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The *Real* NDI Buyer's Guide

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ADMINISTRATIVE INFORMATION

The work described in this document was carried out by personnel from the Naval Command, Control and Ocean Surveillance Center RDT&E Division (NRaD).

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EXECUTIVE SUMMARY

In 1990, the Office of the Assistant Secretary of Defense for Production and Logistics introduced a guide, SD–2, for buying Non-Developmental Item (NDI) systems. The guide was updated in 1995 as DoD 5000.37–H, "Buying Commercial and Nondevelopmental Items: A Handbook," and several companion "SD" guides have been issued. DoD policy recognizes that NDI acquisition represents a cost-effective approach for meeting a variety of system requirements. The guide recognizes that NDI acquisition procedures are not new or significantly different from other types of acquisitions; nevertheless, the guide also recognizes that certain issues must be resolved in order to successfully meet military requirements without compromise while achieving the benefits promised by NDI. SD–2 states in its foreword, "The Department of Defense must explore and implement NDI solutions which provide best value in terms of life-cycle cost, system capability, supportability, and quality." This Center has been involved in acquisition research since the early 1970s and has explored the promises and pitfalls of NDI acquisitions. Much of the early work was documented in the Center's Technical Document 108, "Project Management and Systems Engineering Guide," first published in 1977. Since that time, the policies of acquiring NDI systems have produced additional opportunities to study NDI promises and pitfalls on a greater variety of projects. Many of the pitfalls have been found to be related to the failure to adopt a systems engineering approach to system life-cycle management rather than characteristics of NDI acquisitions.

This document summarizes the best practices and lessons learned in several decades of acquiring NDI systems. These processes have been codified into a tailorable process and several subprocesses. This process has been reconciled with the Center's systems engineering processes and practices to ensure its practical application. The process also introduces the concept of a system life-cycle management agent responsible for overseeing the process application throughout the system life cycle. The heavy application of NDI to system acquisitions raises a variety of very significant issues that must be resolved across traditional organizational boundaries and that require the coordination of a variety of engineering expertise; the system life-cycle management concept provides for this technical coordination and ensures that appropriate expertise is applied to the resolution of these issues.

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WHAT IS NDI?

NDI stands for Non-Developmental Item. This is a deceptively simple definition because it sounds like a single thing or set of things—one set of problems having a single solution. It is not. NDI really defines an entire spectrum of products that have dramatically different properties. As a result, no single set of rules guides the NDI buyer for all circumstances. Nevertheless, NDI poses issues that should be addressed differently from the "build it from scratch" mode of acquisition. This guide addresses the issues encountered during system acquisition from the NDI perspective.

NDI includes the following classes of NDI, each defined by its own unique characteristics and challenges.

OFF-THE-SHELF CLASSES OF NDI

Military Off-the-Shelf (MILOTS)—existing products specifically and uniquely designed for one military application being applied to a new military application.

Government Off-the-Shelf (GOTS)—existing products designed for government applications where the government owns the design. (GOTS is inclusive of all MILOTS, but also includes many other products in both hardware and software.)

Foreign Military Equipment (FME)—equipment equivalent to MILOTS but designed for foreign military applications where the design is owned by a foreign government, including NATO standard items.

Commercial Off-the-Shelf (COTS)—products offered in the open market; the design is owned and controlled by the supplier. See the section on COTS for the definition of different grades of COTS.

Rugged (or Ruggedized) Off-the-Shelf (ROTS)—COTS where the supplier has modified the design to meet the more stringent environments or special characteristics often associated with military applications. See the section on COTS for the definition of different grades of COTS/ROTS.

Foreign Commercial Off-the-Shelf (FCOTS)—COTS where the design is controlled by an supplier that is not domestic to the United States.

NewCOTS—any form of COTS or ROTS that does not have at least 1 year of field experience or support of high-volume/continuous production. An item not in continuous production must have at least 5 years of field experience to not be considered NewCOTS.

Non-Developmental Software (NDS)—any software configuration item that is used without modification and where the design control agent of the software is not the System Design Agent for the application or system being acquired. [NOTE: NDS can fall into any of the classes of off-the-shelf products above.]

Reuse Software—any software that is used without modification and where the design control agent of the software is also the System Design Agent for the application or system being acquired.

NON-OFF-THE-SHELF CLASSES OF NDI

Modified Off-the-Shelf (MOTS)—an off-the-shelf item from any of the classes above that must be modified or adapted through changes to the target application.

Minor Modification—a modification where the scope of the change does not exceed 2 percent of the total product complexity (in terms of parts count, entity count, source lines of code, or other similar uniform measure). (Final percent changes in the design as high as 5 percent are sometimes accepted.)

Major Modification—a modification where the scope of change exceeds that of a minor modification but remains <u>less than a 30-percent change in total product complexity.</u>

Integrated NDI—the interfacing of pre-existing hardware and/or software configuration items to create a new system design.

Integrated Modification of NDI—integrated NDI that also involves the modification of one or more of the configuration items or that requires the development of one or more configuration items to effect the integration of the other items. The definitions of minor and major modification above also apply. In addition, newly developed configuration items cannot in total exceed 10 percent of the total system complexity as measured by a uniform metric. No more than 20 percent of the system functionality should be allocated to newly designed configuration items. System designs exceeding these thresholds should be considered new developments rather than NDI acquisitions.

Two important NDI issues become apparent in these class definitions. The first issue is design ownership. Design ownership requires the control of the design specifications and configuration management of the product baseline (the elements needed to produce and reproduce the product and its supported components). All of the off-the-shelf forms of NDI involve design ownership by an agent other than the System Design Agent. The other forms of NDI involve design ownership of modification designs by the System Design Agent. The second issue is product maturity. All COTS other than NewCOTS can be considered mature. NewCOTS and the non-_OTS forms of NDI have significant system components that are immature. System maturity impacts quality, reliability, and supportability issues. These two issues, design ownership and maturity, form the basis of assumptions that are applied in the various guidelines.

The guidance in this document has been developed and validated through many years of practical experience in buying NDI. NDI has been successfully applied to many unique and specialized military applications. A common misconception is that a unique military application must always result in a unique military design. This is often not the case. Most unique applications still have substantial elements of functionality in common with a broad base of applications. As a result, it is almost always possible to use some form of NDI. In fact, it is very rare to base system functionality on a newly invented technical component; at some level, even systems built from scratch are built of NDI (such as integrated circuits, power supplies, capacitors, connectors) integrated in a new way. The distinction between the class of NDI that involves extensive integration and new design is effectively the same as the distinction between system design and design engineering. To the degree that this boundary can be very fuzzy, so too the distinction between new design and integrated NDI. Developmental acquisitions do, however, share distinguishing features that include the ability to control design features and supporting documentation down to and below the level of system complexity at which the system is supported. The development system is not mature because it is a new design. NDI acquisitions do not have this degree of design control, but the resulting systems enjoy a high degree of maturity.

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DEFINITIONS OF COTS AND NDI IN THE FEDERAL ACQUISITION REGULATIONS (FAR)

The classes of NDI defined above are driven by engineering considerations. The FAR, as a result of the Federal Acquisition Streamlining Act (FASA) of 1994, distinguishes between a "Commercial Item" (COTS, ROTS, FCOTS, NewCOTS, and the minor modifications of these classes) and a "Non-Developmental Item" (NDI including MILOTS, FME, and the modifications of these classes). GOTS is not covered in the FAR. The Commercial Item definition is as follows:

(a) Any item, other than real property, that is of a type customarily used for nongovernmental purposes and that

   (1) Has been sold, leased, or licensed to the general public; or

   (2) Has been offered for sale, lease, or license to the general public;

(b) Any item that evolved from an item described in paragraph (a) of this definition through advances in technology or performance and that is not yet available in the commercial marketplace, but will be available in the commercial marketplace in time to satisfy the delivery requirements under a government solicitation;

(c) Any item that would satisfy a criterion expressed in paragraphs (a) or (b) of this definition, but for

   (1) Modification of a type customarily available in the commercial marketplace; or

   (2) Minor modifications of a type not customarily available in the commercial marketplace made to meet Federal Government requirements;

(d) Any combination of items meeting the requirements of paragraphs (a), (b), (c), or (e) of this definition that are of a type customarily combined and sold in combination to the general public;

(e) Installation services, maintenance services, repair services, training services, and other services if such services are procured for support of an item referred to in paragraphs (a), (b), (c), or (d) of this definition, and if the source of such services;

   (1) Offers such services to the general public and the Federal Government contemporaneously and under similar terms and conditions; and

   (2) Offers to use the same work force for providing the Federal Government with such services as the source uses for providing such services to the general public;

(f) Services of a type offered and sold competitively in substantial quantities in the commercial marketplace based on established catalog or market prices for specific tasks performed under standard commercial terms and conditions. This does not include services that are sold based on hourly rates without an established catalog or market price for a specific service performed;

(g) Any item, combination of items, or service referred to in paragraphs (a) through (f), notwithstanding the fact that the item, combination of items or service is transferred between or among separate divisions, subsidiaries, or affiliates of a contractor;

(h) The procuring agency determines that the item was developed exclusively at private expense and sold in substantial quantities, on a competitive basis, to multiple state and local governments.

The FAR defines a Non-Developmental Item as follows:

(a) Any previously developed item of supply used exclusively for governmental purposes by a Federal Agency, a state or local government, or a foreign government with which the United States has a mutual defense cooperation agreement;

(b) Any item described in paragraph (a) of this definition that requires only minor modification or modifications of a type customarily available in the commercial marketplace in order to meet the requirements of the procuring department or agency; or

(c) Any item of supply being produced that does not meet the requirements of paragraph (a) or (b), solely because the item is not yet in use.

The FAR separates commercial items and NDI such that a commercial item is not NDI; although some NDI may be termed a commercial item. This is a legal distinction made for purposes of the acquisition procedure issues, in contrast to engineering system design and management issues. Both the FAR and this document recognize the substantial differences between existing items and new developmental items and their respective acquisitions. Both approaches recognize that the acquiring agency should not be concerned with the internal design of the item—externally specified requirements are the sole criteria for make a source selection.

GOTS is not included in the FAR definition of NDI. <u>GOTS items are normally produced by commercial production services that would be obtained through commercial item FAR procedures.</u> The policy concerning GOTS production implies that commercial quality procedures, workmanship practices, and manufacturing processes would be used in contrast to extensive acquirer-specified, contractually imposed practices. Government-developed processes should be disclosed for advice only so that the contractor can determine the best means of providing the services required, with the suitability of the end item the sole criterion for acceptance. Where a GOTS item is controlled by detailed design engineering packages exclusively, the policy requires the development of sufficient "performance specifications" for the acquisition and acceptance of the production services. Although this may seem like a considerable burden for the acquisition program, the information is also required for the effective life-cycle support of the item and must be available in any case.

WHY NDI?

Major system acquisitions have often taken a dozen years or more to design and field. Even "small" systems costing only $10 million to develop can take a decade to move from the designer's desk to the field. Over the span of development time, the requirements of those in the field are not being addressed. Furthermore, both the technologies and the requirements tend to change—often very dramatically. This can result in fielding a new system with obsolescent technology that does not meet current threats or requirements. The ability to address military requirements quickly and effectively directly affects national security. Even when the newly developed system does meet the threats and requirements, an extraordinary expense has been borne, often in hidden change costs, to keep the system current. Audits of newly fielded systems have revealed that as much as 60 percent of the development costs were involved in making changes to be responsive to technology and requirements changes; change costs driven by these factors in the 30-percent to 35-percent range are very common. Clearly, new developments always cost more than the use of off-the-shelf items. As budgets shrink but military requirements continue growing and changing, finding solutions more quickly and cost effectively becomes imperative. NDI provides a means of achieving high levels of

systems effectiveness quickly and cost effectively. Department of Defense (DoD) Directive 5000.1 recognizes these benefits and prioritizes the use of NDI ahead of new developments.

Properly applied NDI solutions reduce program risks through the increased ability to be responsive to user requirements, but risks are also reduced because the NDI products generally have a field history that defines their realm of effective application. Developmental systems generally require extensive testing to develop similar levels of application confidence. In changing requirements scenarios, open architectures substantially reduce the costs of changes needed to adapt to the new operational needs. NDI-based systems generally require open architectures for their effective integration; therefore, adaptive changes in NDI systems are frequently cheaper, lower risk, and quicker to implement than new developments.

NDI systems enjoy a broad application base, so the NDI products that make up the systems are generally large, high-rate productions from multiple vendors. Large, high-rate, competitive production bases result in high availability of products and product support items at low cost. Manufacturing risk and the risks of incorporating technological improvements are absorbed by the vendors. Vendor support is usually very responsive since the market share often depends on the vendor's ability to provide responsive support. Product quality is better and less expensive to maintain in high-rate production lines. Developmental systems almost always result in low-quantity acquisitions and very-low-quantity reprocurements for support, resulting in substantially higher support costs from single sources in order to achieve comparable levels of quality and availability.

HISTORICAL BARRIERS TO USING NDI

With these benefits, one might wonder why anybody would ever develop a new system when NDI is available. In fact, a number of barriers tend to divert system designers away from NDI. One barrier is the simple fact that there is a greater benefit to the design agent to develop the product rather than use NDI. Product design allows greater degrees of design control; this is the normal excuse put forward for not using NDI. However, a potentially large profit is associated with product design attached to the cost-plus environment of design engineering, and the risk is transferred to the acquiring agency from the design agent. Also, it can simply be more technically challenging and professionally fulfilling to design the product than to use somebody else's solution.

Another barrier is the set of unique military environments, such as temperature extremes, very high electromagnetic interference levels, unusual environmental exposures, the effects of combat, and unstable power systems. When first analyzing these environmental requirements, it is easy to assume that no commercial product could pass the imposed rigors, but this assumption is usually wrong. Although commercial specifications may not be as extreme as the military requirements, the technologies used are often very robust and can easily be used under the military extremes without modification or with only minor modifications. Of course, this is not the case universally, so there is extra work required to identify potential NDI candidates and to evaluate the potential for their application. Extra work is also involved to resolve the differences between the commercial specifications used to develop an item versus the military specifications associated with an application. This extra work needed is also a potential barrier, especially if there is a predisposition toward building a new product anyway. After all, what if one expends this extra work and finds out that no suitable candidate exists? Then resources will have been expended without a tangible result. The risk of

pursuing an NDI alternative is usually very small but also very real; system designers often overestimate this risk (often unintentionally) in order to justify new developments.

Strangely, one of the main strengths of NDI—quick reaction to satisfying requirements—can also be a barrier. It is much more difficult for an organization to perform a series of quick-reaction, relatively low-dollar programs, than to work a single long-term program. Even with political problems of maintaining a funding line for 10 to 12 years, it is much easier and more secure to do the long-term program than to obtain funding, plan, and accomplish 5 to 8 short-term programs over the same length of time. This problem is mitigated where the acquisition community is supported by a continuing line item of budget; however, this is not the case for the majority of system needs.

Acquisition community managers may also be put off by the fact that many of the life-cycle costs associated with NDI are not markedly different from developed systems, although the cost distribution may be quite different. This can occur because NDI product life spans may be only 3 to 6 years and require frequent system upgrades. Normal engineering changes to a developed system will result in a 10-percent change per year in the product baseline; NDI systems may see a 16- to 30-percent change per year. (On the other hand, system architectures designed to accommodate NDI tend to lend themselves to easy technological upgrades very inexpensively. Systems consisting primarily of developed products also need to be upgraded with new technologies, and these upgrades may be significantly more expensive to maintain per unit of functionality.) Acquisition managers need to take the full life-cycle cost/total cost of ownership impact into account when deciding for or against a NDI acquisition strategy. The initial procurement cost savings can only be preserved in NDI acquisitions when the system upgrade factors are appropriately accounted for in the acquisition planning.

Furthermore, the military support systems are "tuned" to support developed products rather than NDI. NDI systems can be in the field for years and even be approaching the end of product life prior to reaching a designated support date. While shorter support dates may be available using COTS/NDI support procedures, these procedures are still in development. This fact interposes significant challenges to system designers to plan for logistics support, and many designers do not want to be bothered with the added headaches. Consideration of NDI is often viewed as just additional work that is not contributing to "making the dirt fly," so the potential benefits are sometimes ignored rather than pursued.

So, why NDI?—faster, more effective solutions at lower cost and risk. However, NDI solutions are not always available or appropriate. Nevertheless, NDI should always be considered in system architectures and system designs during the requirements definition and conceptual phases of an acquisition.

COMMERCIAL OFF-THE-SHELF (COTS)

COTS STANDARDS DEFINED—DIFFERENT GRADES OF COTS

The designation of COTS is frequently misunderstood. First of all, the term "commercial" is often thought of as merely anything produced by industry (or a nongovernmental entity). Actually, "commercial" refers to a product generated in conformance to commercial specifications. There are three different kinds of commercial specifications: (1) company proprietary specifications, (2) market standards, and (3) industry standards. Each of these forms of commercial specification has its own unique properties that influence a product's potential viability for military applications. Secondly, "off-the-shelf" implies that the product is in production. As noted in the definitions of NDI above, a distinction is made between COTS and NewCOTS with regard to the product maturity. These factors, the form of commercial specification and the product maturity, combine to influence product quality, product life, depth and availability of documentation, reliability, supportability, and training suitability. In addition, the COTS source of supply may be either foreign or domestic. All of these elements are important to take into account when assessing products for use in a system application.

Many of the military specifications were initially generated to overcome the problems associated with commercial specifications. Most of these problems are associated with company proprietary specifications or with market standards. Most of the problems are generated by highly variable quality and reliability factors that drive life-cycle support decisions. Military specifications fixed these factors to enable support planners to complete their tasks. Commercial specifications can lead to very great variances in these areas. Quality and reliability factors are often hard to accurately estimate for support planning purposes for commercially specified products.

Market standards are the most difficult to quantify because the design practices are driven by cost factors to produce the most acceptable product for the market place at the lowest possible price. Market acceptability may demand very high quality, as in medical life support equipment, or may allow very low quality in order to be inexpensive, as in expendable electronic watches or calculators. To assess products designed for market standards, it is necessary to understand the market forces. This may be relatively easy for long-term, well-established markets that are evolving slowly, but it may be very difficult for new or highly dynamic markets. In addition, companies competing in a market may have different market perspectives, leading to radically different design approaches and pricing structures. It is necessary to adequately define the commercial market for any COTS product. Otherwise, the initial assessment of the viability of COTS products will be faulty. For instance, it would not be adequate to do a market assessment of the personal computer market as a whole; it would generally be necessary to distinguish between segments of the market and to identify those segments most closely approximating the target system application. Good market identification allows sufficient analysis to be done to determine the quality and cost factors behind the market segment. Having identified the quality and cost factors, it is then possible to project the likely variables in specification factors (including those that affect supportability) that are critical to a particular application.

A major part of the variability in market standards is termed "best commercial practices" workmanship. Most proprietary specifications have well-defined company practices, and industry standards usually have quality verified by test specifications. Market specifications and the associated commercial practices are driven by market cost. The best commercial practice for a specific market is defined by what is acceptable quality and by lowest possible costs. In markets that involve automated high-volume productions, the quality and workmanship is often defined through the

production processes. However, most products are not produced by extremely automated lines, and high volumes are often achieved through the use of cheap offshore labor. This can lead to very high variability in workmanship standards and high risks associated with support decisions driven by quality factors. Indeed, the best commercial practice for some market segments may be very low quality while a different related market segment might enjoy a very high quality, simply because the quality versus cost decisions are so different for the customer bases that define those market segments.

Proprietary specifications may have excellent performance, quality, and reliability characteristics but still have poor supportability. Most proprietary specifications are closely held by the source of supply and are difficult to document for purposes of training and maintenance. This results in very high levels of assembly for repair and provisioning purposes (i.e., highly complex and expensive lowest replaceable units). The resulting life-cycle costs may be high because of the number of expensive pipeline spares required, or the system availability may be very low due to downtime awaiting parts. This is even more difficult when a foreign source of supply is involved. Products having proprietary specifications are usually only available from a single source of supply. However, there are a few exceptions where an "inventor" source of supply has licensed other manufacturers. Several unique (and mutually incompatible) product designs may be competing in the same market. Here, the system designer must analyze the market and the competing company marketing strategies as well as the technology embodied in the product to determine product viability over the long term. A classic example is the VCR market in 1980 where several formats competed, eventually won by the VHS format in spite of superior quality and performance elements in the Beta format. A different, but closely related market, is the camcorder market now dominated by the 8-mm format, with VHS and VHS-C formats holding a market niche. Good technical logic does not define these markets; but price, product availability, consumer support, convenience, and other factors play key roles. Most of these factors do not relate to military applications. Nevertheless, the products in these markets do have utility in some military applications.

Industry standards are specifications subscribed to and supported by a large number of manufacturers responding to a published industry standard. Many industry standards have been adopted by DoD because the same (or higher) quality and performance factors can be achieved as for military specifications but at a much lower cost. In addition, many industry standards are derived from government-initiated work and become a marketplace consensus standard that is only partially documented in a formal specification forum. Companies may conform to the standard but add special features or "flavors" to give their products a market edge. Some interface standards such as the various Internet protocols could be considered to fall into this category. Variations in industry standards are also illustrated by the various UNIX flavors and variations on instrumentation control bus standards (IEEE–488 versus HP–IB versus TEK–488, etc.). Unfortunately, some of these special features become essential to the applications using the standards, so the application using one enhancement is no longer interoperable with an application using a different flavor of the same standard. Also, some of the enhanced features are difficult to differentiate from the true standard features, so application designers have a very difficult time limiting their implementation to a true standard implementation that will be interoperable.

The commercial standards issue is even more complex when foreign sources of supply are considered. Many FCOTS designs are coordinated proprietary standards because the foreign government or a government-coordinated industry group has agreed to the standards, but the design disclosure is still company proprietary. Usually, an intergovernmental agreement is required to license a domestic

source of supply or even a domestic source of maintenance and training. Such agreements are not always feasible. FCOTS built to the various ISO standards are preferred.

It is important to characterize the commercial market segment for which a product is provided, to document differences between the commercial marketplace and the program acquisition requirements, and to recognize the standards employed in the product design and production. This information is needed to determine the appropriate approaches to the acquisition of the functional item and for its support. For instance, an item having low quality (high variability in performance) may be acceptable if the parent system requirements can be designed to accept the range of variability, but it is more commonly necessary to provide a screening acceptance test to be applied by either the source of supply or by the receiving agency (together with a suitable warranty agreement to cover discrepant items). Products from one market niche may be driven by different factors than those from another segment, so key elements, such as the availability of information needed for support planning or the different flavors of industry standards or the range of contractor support services, may depend on market elements that are not common between the sources of supply. This will drive how procurement documentation is assembled, how support plans are generated, and how the source selection is conducted.

COTS MATURITY

Product maturity is very important in making system support decisions in the use of COTS. Product maturity is a function of production volume and years of service. Products that have been in production and use for many years have an experience base that allows support decisions to be made with relatively low risk. In addition, the design requirements embodied in the product design have evolved in a mature design, so the levels of quality, reliability, and performance tend to be both very stable and relatively high. Documentation for interfacing to mature products tends to be readily available. Commercial support tends to be available and affordable. Even for high-technology products that are susceptible to frequent product improvements, the cost of maintaining a system through repair and selective upgrades is very affordable.

On the other hand, many mature products may lack the high-technology performance edge that may be required in military applications. Mature products may also be based on industry standards that are being superseded by newer technology standards, so the remaining product life may be relatively short. As the transition in standards takes place, companies pull out of the market, resulting in fewer alternate sources, reduced availability of support, reduced operational availability, and high risks of obsolescence. The transition to replacement technology standards often introduces higher life-cycle costs as a system is upgraded than for COTS products not near their end-of-market life.

These kinds of obsolescence problems create pressure to use NewCOTS products that lack maturity. Products that are immature because of the lack of production volume tend to have higher variability in quality, leading to uncertainties and inefficiencies in planning support. Also, most immature products have insufficient documentation, test data, and field data from which to derive training and support information. This does not mean that NewCOTS products should not be considered, but it does mean that added work is required by the system acquisition agent to compensate for these characteristics. This additional work may be in the form of added market research, tailored screen tests, reallocation of system requirements to compensate for product variability, added procurement requirements to reduce the consumer risks, developing contingency support plans, or some combination of all of these techniques.

Companies will often advertise a product prior to its actual design and production simply to find out if a market exists. If they get sufficient inquiries or even orders, then they will invest in product development. This often means that the first production units are really hand-built prototypes. Subsequent manufacture of the item may result in design changes that make the original units obsolete and unsupportable (spare parts may be incompatible; documentation frequently is not accurate). Often the original customers are also the "field test agency" and may suffer many product introduction pains. NewCOTS products may also be changed in order to take advantage of new or evolving industry standards, causing the original designs to become obsolete. New production processes may be brought to bear that may change product tolerances or introduce second-order effects that must be incorporated into system documentation. Both NewCOTS and mature COTS will be continually incorporating design changes, but these changes will usually be forced by different market, economic, and technical issues. The primary difference between NewCOTS and mature COTS is that the design changes incorporated in the normal course of the product evolution tend to cause major supportability problems for NewCOTS, but not for more mature designs.

Some technologies evolve so rapidly that the product life is limited to as little as 6 months. In these technologies, the next generation is in development before the current generation is even in high-volume production. Many risks are introduced through products incorporating high-technology elements. These risks can only be mitigated through careful system life-cycle planning and management that continuously monitors the technology market. System planners can also reduce risk by actively sharing field experience and requirements information with companies developing new products in the market. Although the system management costs are potentially significant to the program, the life-cycle cost savings are substantial because pathways exploiting the rapidly changing market standards can be documented to avoid significant future costs.

COTS products have a range nearly as extensive as NDI products. It is necessary to understand the characteristics of a specific COTS product and its associated market in order to accurately assess the product utility for a particular application and to support the item in the field. There is a continuing need to survey the market from the origination of a product through the entire system life-cycle support phase.

A PROCESS TO BUY NDI

The process described herein is one of many possible processes for buying NDI; however, it is crafted to be both natural and compatible with good processes for developing systems. This results in an approach that results in an NDI-based system whenever good alternatives are available and an open-architecture system development whenever NDI alternatives are not available. A closed architecture development will only result when open standards are not available or when a conscious decision is made toward a closed architecture. Further information on this process is provided in Technical Document 108. The process flows as follows:

1. Define and analyze mission requirements.

2. Determine system functional characteristics (and alternatives thereof).

3. Define one or more technical approaches, giving preferences to open architecture approaches.

4. Define top-level system partitions of functionality along natural lines of requirements (such as operational differences and environmental differences).

5. Partition the system through successively lower levels of functionality, supporting decisions with interface standards selections prioritized by open and industrial standards. Consider technology factors and perform a market analysis of potential NDI at each level.

6. Document the resulting system specifications and obtain industry comments where appropriate.

7. Conduct screens of potential NDI products, documenting integrated logistics impacts and support decision constraints. [Note: A tailored screen may be conducted either independently or in conjunction with the acquisition—see **TAILORED SCREENS FOR NDI**.]

8. Complete the procurement package and proceed with the acquisition, including support. [Note: When NDI products are not available, the procurement package will include development specifications.]

DETERMINING REQUIREMENTS

It is always important to accurately and completely analyze and characterize the requirements of the system; this is even more essential for NDI acquisitions. A failure to establish requirements will lead to system designs that exclude NDI solutions or that incorporate NDI of inferior quality for the application. In setting the system requirements, it is important to characterize the mission requirements and top-level technical requirements in ways that do not dictate a military proprietary design. The system specifier needs to state the mission and operational requirements in a way that can be accurately interpreted by product suppliers. This usually involves transforming operational requirements into their direct technical equivalents while avoiding the trap of framing those requirements in the terms of a specific system architecture. Top-level technical requirements do not dictate one architecture over another, but allow the flexibility for the system designer to choose one or more system architectures as a function of the system partitioning. (See **SYSTEM PARTITIONING FOR NDI**).

Ideal requirements are well defined and stable. It is often not possible to define and stabilize all of the requirements; nevertheless, it is almost always possible to bound areas of requirements that are vague or variable. Merely bounding the requirements areas often allows system design efforts to proceed with firm technical requirements. Different classes of requirements must be defined during the requirements definition phase or early in the conceptual phase of a system acquisition prior to actually determining the system architecture or doing the system partitioning. Although there are numerous ways of defining these classes, the following list has been found to be practical:

Performance Requirements

        Combat capabilities
        Survivability capabilities
        Interoperability requirements
        Safety requirements (includes personnel, product, and environmental system safety criteria)
        Security requirements (physical, operational, electronic, cryptological, etc.)
        Other functional requirements

Usage Requirements

> Usage mode (fixed, airborne, shipborne, deployable, portable, etc.)
> Usage constraints ("must have" versus "nice to have" features)
> Frequency band operating requirements, including spectrum operating rules
> Security code usage requirements
> Satellite resource allocation requirements
> Operating duty cycle requirements
> Mission profile requirements
> Concept of operation requirements/business practice requirements
> Concept of employment/concept of operation constraints

Environmental Requirements

> Operating conditions
> Non-operating conditions
> Combat conditions (conventional, nuclear, biological/chemical)
> Storage and shipping conditions
> Maintenance and repair conditions

Installation Requirements

> Space and location requirements
> Weight and moments requirements
> Power system interfaces
> Other support system interfaces (such as dry air, precise time, stable element outputs, etc.)

Human Factors Requirements

> Operator personnel—fully trained
> Operator personnel—reduced grade and training levels
> Operator personnel—combat stressed or fatigued
> Organizational maintenance personnel—fully trained
> Organizational maintenance personnel—reduced grade and training levels
> Organizational maintenance personnel—combat stressed or fatigued
> Intermediate maintenance personnel
> Depot maintenance personnel
> Installation personnel

Electromagnetic Compatibility Requirements

> Electromagnetic interference—susceptibility (conducted and radiated)
> Electromagnetic interference—conformance (conducted and radiated)
> Electromagnetic pulse
> TEMPEST criteria
> Hazardous electromagnetic radiation (fuels (HERF), ordnance (HERO), and personnel (HERP))
> Electrostatic discharge susceptibility/protection
> Shielding, bonding, and grounding requirements
> Abnormal conditions (lightning, power system spikes and transients)

Supportability Requirements

       System life requirements
       Operational availability requirements
       Mission reliability requirements
       Life-cycle (support) cost constraints/requirements
       Fault/failure criteria
       Maintenance criteria
       Downtime constraints/requirements
            Maintainability characteristics and requirements
            Downtime for parts requirements
            Downtime for assistance requirements
            Administrative downtime requirements
       Personnel constraints/requirements
       Training constraints/requirements
       Packaging, packing, and preservation requirements
       Handling, storage, and transportation constraints and requirements
       Limitations on evacuation of repairables
       Interchangeability of spares requirements/constraints
       Operational logistics constraints
       Technical data constraints/requirements

Production Requirements

       Initial quantities and rates
       Follow-on quantities and rates
       Foreign military sales/cooperative production agreement requirements
       Spares acquisition requirements

Technical Interface Requirements

       Interface standards and protocols
       Computer operating system compatibility
       Minimum computer hardware support standards (speed, processor type, output ports, etc.)
       Minimum expansion capabilities

Programmatic Requirements

       Affordability criteria (both acquisition and life-cycle support)
       Crown Jewel performance criteria (priority user requirements and minimum acceptable criteria)
       Schedule constraints (such as delivery prior to a specific mission or operation)
       Risk constraints

Each class of requirements contains elements critical to the overall effectiveness and suitability of the system. These requirements must be identified for system test planning as well as for system design and acquisition. The requirements apply whether the system is to be designed from the ground up, integrated from existing components, adapted from off-the-shelf items, or some hybrid of these approaches. If the requirements are properly defined, none of these approaches will be precluded. Also, these requirements are interactive with each other, so the requirements relationships must be determined at least qualitatively, although quantitative relationships are desired and often must be

derived in order to complete a system design. Doing a thorough job of requirements definition greatly contributes to making build/buy/modify decisions during the system partitioning phases of system design.

Military applications do have extremes in performance envelopes, environmental requirements, and support requirements that can greatly exceed normal commercial specifications. Nevertheless, these extremes are usually not experienced simultaneously nor for long periods of time, so the product stresses are usually within the technical capabilities of high-quality products built to commercial specifications. Also, environmental extremes in military platforms are usually isolated to relatively small areas of the platform, and combat extremes are usually short in duration. The environmental requirements for military applications are often used to exclude COTS products from consideration even though the actual environment on the platform may be very similar or even less stressing than some commercial environments. For example, the simultaneous extremes of high temperature and high humidity, Navy-peculiar requirements, rarely occur aboard Navy ships and are confined to limited areas of the engine rooms when they do occur. Most combat spaces must be controlled to less stressful conditions than commercial specifications because people must be combat effective in these spaces. Although mission profile analysis may provide useful insights to combined environmental stresses, field measurements are usually required to determine the specific environmental limits.

The most common areas left underdefined are in the areas of human factors requirements and supportability requirements. The failure to adequately define these requirements leads to high life-cycle costs no matter what kind of system is being acquired. Inadequate information will be available to the system designers and the subsequent design engineers developing a product or evaluating NDI alternatives, resulting in poor decisions in the system life-cycle support area. Most commonly, support requirements will dictate higher levels of operational availability than will result from normal support decisions. The use of COTS can be very expensive when it is necessary to achieve high operational availability performance. When costs of support are controlled, operational availability will suffer because of excessive downtimes. NonCOTS NDI forms may also be similarly affected. This is also a failing of most newly designed/nonNDI systems. The failure to adequately define these requirements often results from acquisition managers failing to recognize the importance of the requirements, thereby failing to task and to fund the efforts needed to do the requirements analyses in these areas. Also, these requirements areas can be rather vague and can lack well-recognized quantitative requirement statements, resulting in even more effort to properly bound the requirement variabilities and to define the requirements in usable quantitative terms.

In even the most state-of-the-art systems, at least 80 percent of the system functionality has already been done before. If the functionality has been done before, it almost always exists in a NDI form; therefore, NDI candidates ought to be considered as a routine part of a system design implementing virtually any set of requirements. Only requirements that are truly new or that need to be advanced by the state of the art should require new development.

While substantial portions of the system functionality have already been done before, it is important to analyze the operational requirements in a way that does not automatically assume that performing operations "the same old way" is the correct approach. Operational requirements analysis should start with the mission definition in its broadest terms. Failing to take this approach will result in "same old way" operational requirements that will preclude the best use of available technology. Some of the best system designs anticipate how technology will enable future changes in concepts of operations and usage doctrine. This implies a large amount of concurrency in the analysis of the

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operational requirements, the top-level system partitioning decisions (see **SYSTEM PARTITION-ING FOR NDI**), and the assessment of technology implicit in conducting a market survey as a part of performing the system partitioning.

In defining, analyzing, and determining requirements of all forms, it is also useful to determine the various methods that might be employed to verify the requirements. This analysis can be used to determine the most effective means of achieving the desired system quality. The avenues of approach may vary from acceptance of the market quality to extensive testing tailored to qualify the products for the application. Effort in the area requirements analysis and verification early in a project will save orders of magnitude in future costs over a system life cycle.

SYSTEM PARTITIONING FOR NDI

System partitioning is the art of allocating system functionality (and other requirements) into a hierarchy of product cells. Top-level cells are the most complex and contain the most functionality, while the subsidiary cells are relatively non-complex and contain limited functional implementations. The traditional levels of complexity are system, subsystem, set, group, unit, assembly, subassembly, module, and piece part. The allocation of requirements to these levels also defines levels of repair, levels of standardization, levels of design ownership, and the levels at which the acquirer (government) is responsible for system integration decisions versus the supplier. Each act of partitioning creates a series of internal system interfaces and defines a piece of the system architecture. Generally, the cells interface with each other at the same level, so partitioning decisions can be made independently for one part of a system than for another part. Even when one portion of a system is not amenable to NDI, that does not preclude the use of NDI in other portions of that system.

The partitioning decisions consider the requirements flowed down to the level of complexity at which the decision is being made, plus an assessment of available technologies needed to implement those requirements. The assessment of available technologies takes into account any products that address similar functional requirements. The step often missing in this assessment process is the one that analyzes each product for its viability and utility in addressing the full set of requirements at that level. The conduct of this assessment is greatly enhanced by good requirements flowdown processes and tools. A good knowledge of the underlying market associated with the product is also needed. The technology assessment often does not include NDI products because the market knowledge is not immediately available. Good partitioning processes also look ahead to the standards and products that exist at lower levels of complexity that are exposed when one decision is made versus another. The look-ahead process helps to avoid deciding to favor a good proprietary design that implements a very high level of standardization when excellent and more cost-effective designs could be easily implemented at a lower level of complexity. NDI can also be neglected when good requirements flowdown processes are not being used, hampering the ability to look ahead to the impact of various standards at lower levels of complexity.

The system partitioning decisions should be looking ahead to NDI use, consistent with the DoD policy that establishes an order of preference for NDI as follows:

- (Non-materiel options not requiring item acquisitions.)
- MILOTS, not involving additional production.
- Modified MILOTS, not involving additional production.

- Other _OTS, especially commercial items (as defined by the FAR).
- NDI (unmodified, including MILOTS) (as defined by the FAR).
- FME.
- Modified _OTS or FME.
- Integrated NDI.
- (Joint-Service Development).
- (Service-unique Development).

This order of preference should be considered at each iteration of the system partitioning process. Costs, risks, supportability, safety, and human factors should be considered in evaluating each alternative. Large or complex systems may be an integration of several of the above categories.

SYSTEM ARCHITECTURES

A system architecture summarizes the character of the standards that interface the cells of the system partitions. The system architecture is actually defined by the common philosophy used in making the system partitioning decision rather than being an imposed structure. When a system design is initiated, there will be architectural policies; however, the actual architecture will be consistent with those policies only to the degree that the system designers use standards having characteristics that agree with the policies. In fact, this might not even be possible in those cases where the technology is not supported by standards consistent with the policies.

There are two basic types of system architectures: open and closed. An open system architecture consists of standards that are available for public use. Availability for public use means that the standard information is published in a public forum, that the standard can be used without legal restrictions, that the interfaces are fully characterized, and that the technology is publicly accessible. All other architectures are closed because the interfacing standards must be obtained through some means of legal agreement, through the release of special design documentation, or through special characterization tests. Virtually all MILOTS and FME and Non-OTS NDI products use closed architectures with only subsets of the product being in an open architecture. Proprietary and market-driven COTS, ROTS, and FCOTS products are inherently closed architectures, requiring extra actions to become open standards. Only those designs using industry standards, widely accepted market standards, government coordination standards, or international standards can qualify as open architectures. In addition to being available to the public, an open architecture should also be widely accepted in order to gain the desired benefits (i.e., cost savings throughout the life cycle). Wide acceptance also implies strong market competition. Low acceptance means limited market competition, leading to potential sole source procurements. An open architecture is still preferred over a closed architecture, even in a low market acceptance circumstance, because the low market acceptance may be caused by recent acceptance of the standard or an immature market waiting for users like DoD. But multiple standards may be available for which the market has already expressed a preference; select the architectural standards dictated by the market where possible.

An open architecture is sometimes referred to as a "standards-based architecture" although open architecture is a broader term that also recognizes market standards, not merely published industry standards.

Open architectures are much preferred in order to utilize NDI. In fact, open architectures have characteristics that make them preferred whether NDI is used or not. DoD and Navy policy is to use open system architecture, with various agencies even defining which sets of standards are desired over others that are available and that meet the criteria of being open standards. Open architectures have three primary advantages: (1) flexibility in meeting new or changing requirements, (2) flexibility in adopting new technologies, and (3) lower life-cycle support costs (due to lower modification costs). The flexibility of open systems can be a major advantage when using NDI because support can be generated over the long term even when suppliers and technologies are short-lived. This is especially critical for COTS products in emerging technology, highly competitive markets populated by small businesses. Open architectures can also be used to define product requirements that are stable even when the operational requirements and threats associated with the application are ill-defined or highly dynamic.

The personal computer industry provides a classic example of the effects of architecture. The original IBM PC was an open architecture because IBM published the information for interfacing to its BIOS and bus structure and did not require licensing; the Apple Macintosh was a closed architecture because Apple required licenses to enforce conformance to its published standards and not all of the standards were published. In both cases, the interface design was company unique and controlled by the original design activity, characteristics of proprietary standards. The IBM standard became an open standard because it was openly published and quickly adopted as a market standard. The closed architecture allowed Apple to control quality, user interface, upgrade compatibilities, and application interoperability; these were haphazard features on the IBM. The open architecture allowed a myriad of third-party interface products and application products to become available quickly. This had the immediate effect that costs dropped quickly for IBM standards-based products, and applications meeting newly discovered requirements were rapidly developed. Even though the early days of the PC industry had many start-up companies that were short-lived, support for the open architecture products became much cheaper and more readily available than for similar closed architecture products. Ultimately, new technology products became available for the open architecture much more rapidly and less expensively than for the closed architecture.

The more normal form of open architecture is that created by system designers. In this form, the system designers perform the top-level system partitioning using industry standards as prime selection criteria while looking ahead to the potential for using existing products. The terminal sets recently specified for various Navy communications requirements serve as good examples. These architectures are all very similar. Much of the functionality is allocated to software residing on a Navy TAC workstation. The TAC workstation program uses the DoD and Navy standards for open systems. This provides a stable environment for the acquisition and life-cycle support of the software applications, including the use of NDS. The form and fit of the hardware is specified to conform to industry/ISO-recognized packaging and interface standards, such as VME bus, VXI bus, 19-inch racks, and various standard LAN standards. This approach minimizes the proprietary design features when they do exist and typically isolates the proprietary features to only a few subassemblies; the approach also promotes commonality with commercial communications terminal equipment and raises the potential for using NDI, especially COTS. If the terminal equipment is not a COTS design, it is often integrated NDI where most of the integration design "glue" is implemented in software. (Proprietary and other closed architectures may often be converted to an open architecture, if sufficient product interface information is available, by encapsulating the closed architecture items in interfacing products that translate the interfaces into an open architecture set of standards.) Although terminal sets with this architecture may have high initial support costs, the initial

acquisition costs and life-cycle support costs can be very low. The sets are inherently easy to reconfigure to new communications protocols, easy to upgrade with new technology, and cost effective to support as long as proper logistics decisions are put into place.

INFLUENCES OF CURRENT TECHNOLOGY

Technology advancements are constantly influencing how system partitioning decisions are made. New technologies lead to new interfacing standards. These new standards usually migrate from being company proprietary to market-driven to industry standards over time as the technology becomes more widely accepted. Some companies, especially Hewlett-Packard, IBM, and AT&T, actively pursue establishing new technologies that they have developed as industry standards. These companies participate heavily in industry standardization activities. While the company risks losing business to competitors joining in the industry standard, the industry standard promotes a rapid incorporation of the technology into a variety of products that promotes rapid market growth. The rapid market growth quickly raises production volumes, lowers production costs, and increases the profitability of the companies positioned to take advantage of the changing market conditions. Often, this creates more than one standard for a particular function, each based on a different technology. It may also create a hierarchy of standards sometimes called an architectural suite of standards. In an architectural suite, a series of tiers or layers are defined to connect the physical implementation standards to the application or user standards. The intervening layers may provide a variety of different standards, usually called protocols, so that selecting a standard from each layer results in a defined capability. Each defined capability is supported by a stack of standards called a user or application profile. A given application or user function may actually be supportable by a variety of profiles, and the system designer usually strives to define profiles across all of the system user functions that have the least variability in the lowest layers of the stacks.

This approach is substantially different from system partitioning before 1970. Originally, system partitioning was confined to the best means of implementing a system function—in mechanical, electrical, or electronic hardware, or by the human operator. Software implementations started to become available in the 1950s, but the functionality options were severely limited by technology. In the 1980s, the price of computing hardware dropped very dramatically and software technology barriers were rapidly torn down, rapidly transforming the options available to system designers. At the same time, microelectronics advances created the new design options of programmable hardware, production tailorable hardware, and cost-effective, application-specific integrated circuits (ASIC). The number of options available to a system designer has continued to grow exponentially. The number of solutions leading to proprietary standards has kept pace with the rapid growth of industry standards, so the challenge to the system designer has become a double exponential growth. As a result, building and analyzing user profiles is but one of the ways that system designers can organize and understand the impact of the many competing standards.

The capabilities of new technology have led to the development of a generic system architecture. This generic architecture consists of a high degree of functionality allocated to software running on a standard computing platform. The computing platform is supported by ASIC or programmable hardware technology to adapt the platform to specific and unique application environments that cannot be readily expressed in software. Some other hardware may be required for the physically expressed functionality (such as engines or armor or munitions or antennae), but it is minimized. Every reasonable effort is made to avoid allocating functions to human operators. Within the software, the functions are expressed as objects. Just as the functionality breaks down into less complex components, so the top-level software objects can be assembled from lower level objects. At every level, there are

a multitude of options for selecting different types of standards and different technology standards of each type. The system designer needs to be very knowledgeable in the standards options and the associated markets. The range of choices can be mind-numbing, but it also increases the chances that viable NDI products or standards will exist to satisfy the system requirements.

The cleanest way to express software functionality in a system architecture is to partition the software such that all computer software configuration items (CSCI) reside on a single processor. This allows easier control of the hardware/software interfaces and promotes testability and system maintainability throughout its life cycle. However, evolving software technology has defined super-objects that can bridge or adapt to changing system states to further reduce the need for operator intervention. These super-objects are frequently called system agents. Software agent technology usually results in expressing the agent in the system hierarchy above the processors hosting the software; the agent is truly distributed across multiple processors. This introduces significant challenges to the system designers and life-cycle agents because the hardware/software interfaces must be carefully controlled to provide a stable platform for the agents to operate properly. However, the underlying processor technology is subject to very rapid changes. This circumstance requires the system designers and life-cycle agents to maintain a very detailed configuration status of both the hardware and software and to continuously research and test hardware items against this interface in order to keep the interface up to date as the technology changes.

If a particular function finds a sufficient market, the products embodying that function will be subjected to continuous technology insertion and product update. As an example, disk controllers in early personal computers were discrete component designs on printed wiring boards using very simple integrated circuits. Over the years, the function has been sufficiently standardized and integrated into programmable gate arrays and application specific integrated circuits, allowing the function to be combined with many other functions or to be included with the computer's motherboard. Later generations may include other related functions such as caching and error correction and compression. This same migration of functionality from assemblies to subassemblies to components is enabled by the combined forces of market economics and the advances of current technology.

Generic architectures, software technology advances, and hardware production advances each introduce significant challenges to maintain a system configuration. All of these factors are usually at work in modern systems, so configuration management becomes an ever greater challenge, especially for NDI-based systems. These challenges imply important changes in the way configuration management is done, but the new problems are solvable. See **CONFIGURATION MANAGEMENT (CM) ISSUES**.

MARKET SURVEYS

At least four different types of market surveys are appropriate for the different phases of a system life: market identification survey, initial market survey, acquisition market survey, and system support market survey. Each of these survey types share common features, so it is often possible to perform the survey functions in parallel. The market identification survey gathers information to identify what market(s) may exist to support a particular set of system requirements and to characterize the economic forces and quality factors driving the market(s). The initial market survey identifies the standards, suppliers, and products available to support the identified system technical requirements. The acquisition market survey is conducted to identify the suppliers that define the competitive range of a specific acquisition plan or contract action in accordance with the Federal Acquisition Regulations (FAR) and the Defense Federal Acquisition Regulations (DFAR). A system support

market survey gathers information about the stability of product interfaces against system requirements and evaluates repair versus replacement versus technical upgrade opportunities through the system life-cycle support phase. Each of the surveys contributes valuable information for making program decisions, and the survey results should be well documented in a form readily accessible by the program decision makers.

A market identification survey is most efficiently and effectively conducted by one to four engineers practicing in the technology and keeping up to date in their field through trade journals, conferences, short courses, and so forth, supplemented by economic data on the suppliers in the market. If there are multiple key technologies, multiple survey subgroups of engineers can be used to gather all of the information needed. The engineers involved in the system specification and design are usually well qualified for the survey tasks.

An acquisition market survey must be conducted consistently with the FAR and DFAR, but may limit the competitive range of suppliers. For instance, the acquisition market survey may exclude vendors that are not currently in production in favor of suppliers who are able to deliver directly from stock, using program schedule and risk criteria as justification. Other criteria for including or excluding suppliers from the competitive range may include the availability of field data or test documentation, quality criteria, the availability of suitable support services, various costs, or performance factors. A sufficient competitive range must remain to ensure adequate competition. The quality of the survey documentation can often be critical to avoiding protests in subsequent contracting actions.

Initial Market Survey

The initial market survey should be considered a mandatory part of the system design process of establishing system partitions. For NDI acquisitions, the survey continues into the procurement phase, and should be transitioned into a system support market survey for the support of the system (in order to make effective item replacement decisions). For developmental acquisitions, the survey is handed over to the design engineer, who continues a mini-survey on the assigned portion of the development. The initial market survey consists of the following activities:

1. Surveying existing standards that address functional requirements.

2. Surveying potential suppliers and the market economic and quality factors.

3. Surveying existing products and technologies.

4. Obtaining additional information from suppliers and users of candidate technologies, especially cost data.

5. Obtaining additional information from suppliers and users of candidate products, including test data, quality data, reliability data, usage data, cost data, supportability data, and environmental data.

6. Developing a tailored screen to supplement information not completed otherwise and to determine the viable candidates.

7. Adjusting requirements through industry comments on procurement requirements documents (specifications, statements of work, and contract data requirements lists).

The initial market survey through step 5 should be a part of every acquisition, including new developments. The survey should incorporate expertise covering reliability, test, quality, integrated

logistics, and documentation as well as the functional technology expertise. This expertise should be combined to characterize the technology and economic factors that drive the product market. Even if an off-the-shelf option is not eventually selected, this market characterization can be used by the system designer to select a viable architecture and appropriate standards to minimize the system life-cycle support costs. The system designer should ensure that the results are documented for use during the procurement phases that will follow the system design. NDI introduces issues in each of these areas.

In addition to evaluating technology factors against requirements, the initial market survey should also evaluate cost factors. This is especially important for high-technology items and rapidly changing technologies. In general, product costs are high when the product is first introduced on the leading edge of the technology market. Prices come down as the product matures and the market demand supports high production rates and the investment in manufacturing efficiencies. As the technology matures, new products are introduced that take advantage of the latest innovations; these products often go beyond a mere product improvement and usually establish new standards for interface as well as performance. It is important to ascertain where a product is in its life cycle, and the cost factors provide a substantial insight into the product maturity. Figure 1 shows a typical product life-cycle cost curve. Figure 2 shows typical relative costs for competing technologies on the open market.

Figure 1 only refers to the product cost off-the-shelf over the product's life cycle on the market. It does not refer to the costs that will be incurred to support the product in the field. However, support costs for an item will also follow a similarly shaped curve since the support items are produced on the same production lines. After the production line is closed down, support items are provided from inventory. Market costs tend to rise because inventory management costs must be recovered. Also, there may be a residual demand competing for the increasingly scarce product, combined with diminishing sources of supply as companies shift their production assets to the newer product lines. Eventually, the shelf inventory will be used up, and true parts can only be obtained through the surplus market or from a reopened limited production line. Clearly, the surplus route introduces
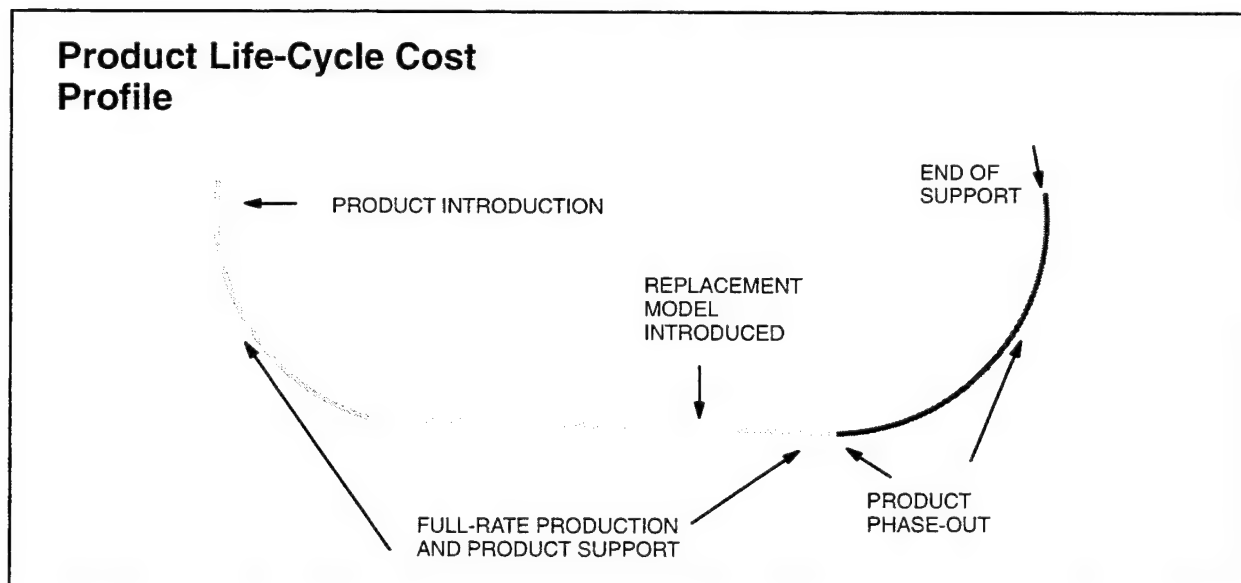

Product Life-Cycle Cost Profile

PRODUCT INTRODUCTION

END OF SUPPORT

REPLACEMENT MODEL INTRODUCED

PRODUCT PHASE-OUT

FULL-RATE PRODUCTION AND PRODUCT SUPPORT

Figure 1. Typical product shelf cost over its life cycle.

Technology Cost Edge

LOWEST PERFORMANCE

HIGHEST PERFORMANCE
**LATEST STATE
OF THE ART**

ESTABLISHED TECHNOLOGY

IDEAL BUY
POINT

**SURPLUS
TECHNOLOGY**

1995 HDD EXAMPLE

10 to 40 MB   100 to 500 MB   800 to 500 MB >3 GB
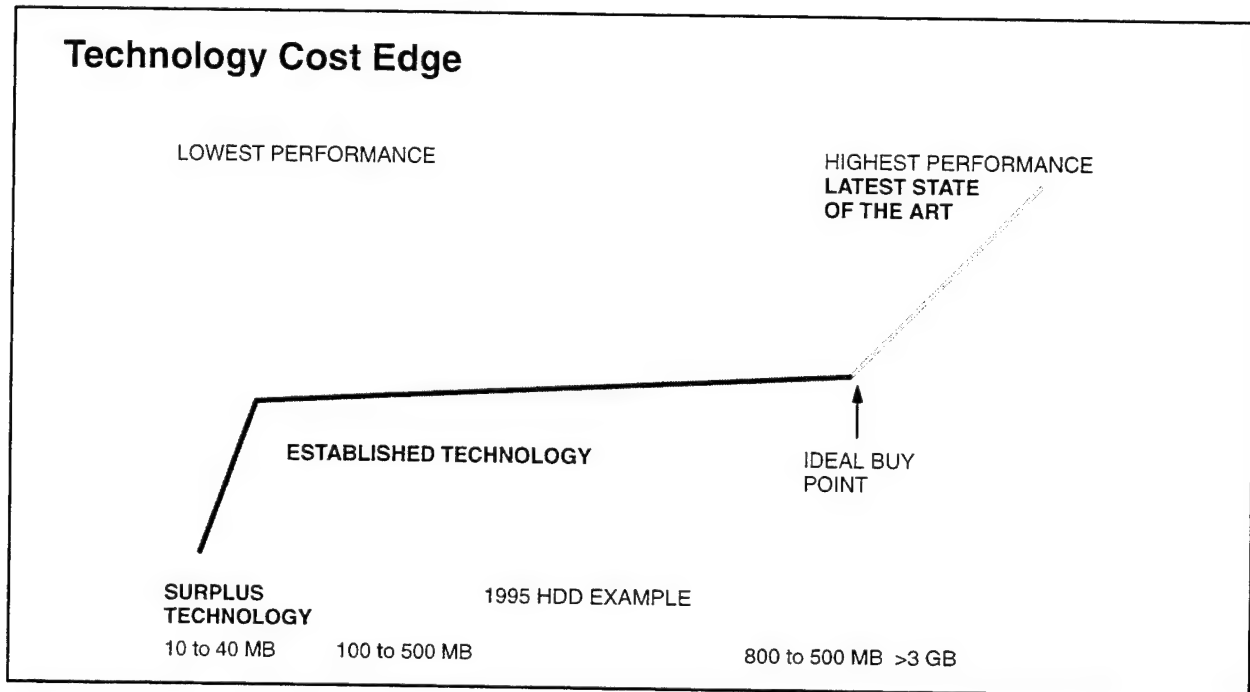
Figure 2. Relative costs of competing technologies.

huge quality risks since items may have been scavenged from equipments taken out of service for unknown reasons. Opening a limited production line is very expensive. Quality on limited production runs is often very difficult to maintain, representing a significant risk. Clearly, the choice is to avoid both surplus and limited production situations.

Figure 2 illustrates the typical relative costs, citing the example of hard disk drives for personal computers in the late 1995 time frame. The 10- to 40-MB hard disks primarily represent MFM interface technology. These disks were not only smaller in capacity, but larger in size and weight and much slower in access times. However, they were still available in the surplus market for about $1 a piece, although most vendors could not guarantee their operation. The 100- to 500-MB drives were primarily early IDE drives. Although most vendors did not stock this size drive in late 1995, prices were in the $80 to $160 range. The 800- to 1600-MB drives represented the mature edge of the technology in late 1995, with prices running from $180 to $275 (plus some variance between vendors). A 1.6-GB, extended IDE Mode 4 drive was the buy of late 1995. Drives of significantly higher capacity were typically SCSI technology and were available at a somewhat higher cost per MB of storage, but had very fast access times. Also, various optical storage technologies started becoming price competitive in 1995, but access times and transfer rates were still behind hard disk technology. The relative costs represented by these numbers are very typical across any technology that has a significant market with a lot of market growth as well as high levels of technical innovation. The ideal buy point is highly time sensitive and the performance represented at this level constantly changing. Markets without these levels of growth/innovation will have similar cost curves, but the time represented from edge to edge will be much longer than for the truly high-technology markets.

It is important to choose a correct metric model in evaluating price and performance in the market. Take the hard disk drive example. A "price only" model will dictate buying something off of the surplus market, so a 40-MB MFM drive for $1 is likely to be chosen. A "performance only" model

will likely drive the selection toward a 90-GB SCSI drive for $200,000. A "comprehensive" model properly balancing a variety of performance factors with price will likely choose a large, fast extended IDE or SCSI drive, depending on the performance factors that are important. In late 1995, the likely choice would have been an extended IDE drive with a 1.6-GB capacity and 9- to 10-ms access time for about $240. Figure 3 illustrates these choices.
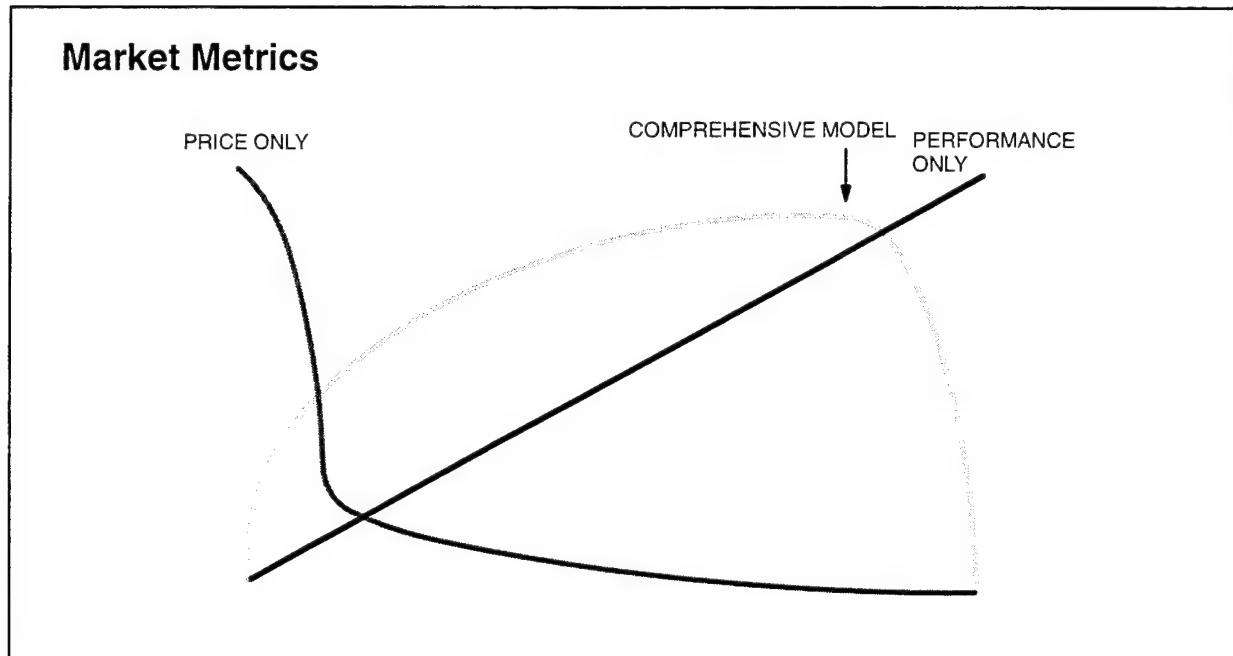
Market Metrics

PRICE ONLY   COMPREHENSIVE MODEL   PERFORMANCE
                                     ONLY

Figure 3. Metric models in market evaluations. Different metrics produce dramatically different decision points for price and performance to meet requirements.

Different acquisition programs will have different priorities, so the metric models for evaluating the market should reflect these differences. There may or may not be a common solution for several projects containing similar functional requirements. Selections should initially be based on the immediate acquisition project requirements. After a workable system architecture has been selected, then alternatives influenced by commonalities with other systems should be considered. The system partitioning decisions should be standards driven. However, the standards may reflect the rapidly developing technology within a market, industry standards, or previously adopted standards already supported for other projects. Large acquisitions should tend toward the latest market standards while very small acquisitions should tend toward previously adopted standards. These are the decisions that will be reached as a result of a life-cycle cost analysis. Small acquisitions that share standards with other projects should share the life-cycle management resources of those other projects as well to obtain the benefits of mutual upgrades. See **SYSTEM LIFE-CYCLE PLANNING**.

System Support Market Survey

System support market surveys are very similar to initial market surveys, and the initial survey can be flowed into the system support survey for NDI acquisitions. Although system support market surveys may be conducted occasionally as part of a product improvement acquisition or when spare part availability problems arise for developed systems, they must be conducted virtually continuously for systems employing high-technology, off-the-shelf products. The system support market survey consists of the following activities:

1. Surveying existing interface standards associated with the system support products, including the market economic and quality factors and the incremental product changes (in relation to these standards).

2. Surveying new related products and technologies, especially cost data.

3. Obtaining additional information from suppliers and users of candidate products, including test data, quality data, reliability data, usage data, cost data, supportability data, and environmental data.

4. Developing a tailored screen to supplement information not completed otherwise and to determine the viable candidates.

The system support market survey is limited to the identified level of repair for the system (such as for a specific VME card or software product), unlike the initial market survey that is applied iteratively to the many levels in the system partitions. In practice, most of the survey effort is embodied in obtaining test items in order to screen minor modifications in the products that make up the system, especially in those products that are available from multiple suppliers. This effort can be limited, but there needs to be sufficient effort so that product interfaces (especially hardware–software interfaces) can be evaluated ahead of having to make repair, replace, or upgrade decisions.

TAILORED SCREENS FOR NDI

Screens are special investigations and tests conducted to identify and certify products are viable for application to a defined set of requirements. The basis for the screen is always the well-defined requirements established early in the acquisition program. Ideally, these requirements are complete, stable, clear, concise, measurable, and stated in terms that can be applied directly to the system design problem. Seldom are requirements so well behaved. Usually, requirements are incomplete in some major areas (especially support and human factors requirements), subject to substantial changes, stated in terms that are incomprehensible, unmeasurable, and difficult to interpret in system design terms. Prior to proceeding with system partitioning actions, it is necessary to conduct detailed requirements analyses to resolve the differences between the ideal and the reality. In the process of conducting the requirements analyses, it is helpful to also conduct investigations into the markets that could provide potential NDI products. Even if no viable products exist, these investigations establish a baseline for what constitutes the state of the art for the operational requirements; this information is needed to write legally viable contract specifications and aids in conducting the initial market surveys during the system partitioning phase of system design.

Having established the requirements, the system designer proceeds with the system partitioning decisions. At each level of complexity, the appropriate standards must be identified. In most cases, these standards are embodied in existing products, so a search of the existing markets for products is a quick means for gathering the desired standards information. The existence of NDI greatly promotes system design. Furthermore, the NDI can be used to form a baseline comparison system. The baseline comparison system represents all of the required system functionality as expressed in the existing products. The NDI included in the comparison system does not have to include viable candidate NDI for inclusion in the system under design, merely to represent similar functionality. Such a comparison system is extremely useful in performing logistics analyses and in defining the nonperformance systems requirements. It is unlikely that any part of the new state-of-the-art system being acquired will have many of the product elements of the baseline comparison system; nevertheless,

the actual field data gathered for the baseline comparison system is significantly more reliable data for making support decisions than the models and forecasts arising from pure analyses. Using NDI in this way naturally exposes potential viable candidates for inclusion in the new system.

As the system partitioning for the first two of three levels of complexity is completed, a host of high-level products and standards will be identified. Also, the top-level requirements should be well defined at this stage. A further market analysis looking ahead to the lower levels of complexity will further identify candidate NDI. However, a large number of the NDI candidates are likely to be designed against proprietary standards or market standards that are undefined—unknowable to the system designer or so highly variable as to present a significant system design risk. For the various forms of MILOTS, the system designer needs to check the specifications and test reports for the items to see if there are any deviations or waivers on requirements or other nonconformances to requirements that are critical to the new design and also to determine the technical assumptions and conditions of the specification or report. For items in production, it is useful to check production quality records to see what the defect rates are and to characterize the nature of the defects. Many sources of supply are required to keep such records, and the records can be disclosed under ISO9000 (and MIL–Q–9858) quality provisions. Field data should be available for all forms of _OTS, except NewCOTS. All of this data allows the system designer to narrow the field of likely candidates.

The field of likely candidates can be narrowed even more by eliminating those that do not meet the hard technical requirements and those that cannot conform to the system acquisition constraints (such as cost or support requirements). The remaining candidates will include those that are truly off-the-shelf and those that are not. The candidates that are not off-the-shelf may include many NewCOTS and some military equipments that are not in production and that are available only after a sufficient quantity is needed (then the equipment must be "redeveloped" for each new production run). Of all of the remaining candidates, it is unlikely that any will meet all of the requirements flowed down to the product level they represent. Each candidate must be assessed for the ability to modify or to isolate the candidate in such a way that the nonconformances can be accommodated in the system design. For instance, a particular candidate might not be capable of withstanding the severe shock and vibration of a shipboard environment, but a suitable installation kit can provide sufficient isolation for the candidate to remain viable. An off-the-shelf software package might not include a particular interface function, but an included macro language capability might allow the functionality to be added in easily. An item might have unsuitable human factors, but the item can be hidden behind a shell that does provide the required human interface. An item may have a highly proprietary design, but support can be provided so that repair of the item is not needed above the depot level. In each case, the costs of the adaptation, modification, or other accommodation must be assessed. This includes the acquisition and the support costs. In the end, there will likely remain a number of potentially viable candidates, and a number of risk areas will be identified where the candidate's performance is either variable or unknown.

The potential candidates can be prioritized based on the conformance to the system requirements, their success as products, and their overall suitability. (Suitability might be indicated by high field reliability experience, inexpensive long-term warranties, specified ruggedness, high customer satisfaction, or high market share.) A screen can now be applied against the requirements to determine the product viability within the proposed system design. The screen should consist of the following elements: visual inspections, data reviews, and tests. Application of the screen will eliminate some candidates and validate others. Those that are validated can also be rated technically for contracting purposes, based on the screen results and published contract evaluation criteria. (See **SOLICITATION AND SOURCE SELECTION TIPS.**)

Candidate equipment should be inspected for at least the following attributes: workmanship, enclosure effectiveness, human engineering, safety design, maintainability, operability, thoughtfulness of design (functional design integrity, flexibility for adaptation or modification, and producibility), and vintage of design. Major and minor discrepancies should be noted. Major discrepancies are cause for rejection if they cannot be corrected through simple modifications. An archaic design may be cause for rejection unless the supplier can guarantee support for a time compatible with the required product life. A design that is too new (experimental or unproved) may inject significant risks that must be addressed in the overall acquisition strategy.

The data review should include all available specifications, test reports, technical manuals, instructions, schematics, procedures, and installation data. These data items should be reviewed for consistency and completeness, comprehensibility, and utility. For hardware items, the following elements are useful indicators:

- Net input power/volume (an indication of heat buildup and reliability).

- Operating temperature (an indication of component design limitations and humidity resistance).

- Cooling capability/net input power (an indication of cooling effectiveness).

- Internal voltage levels (another indication of humidity resistance and potential safety problems).

- Equipment weight, volume, shape, and mounting provisions (indicators of shock and vibration resistance, and interface or installation problems).

- Manufacturer's claimed environmental, reliability, and interface specification conformance, if any.

- Component weight, volume, shape, and mounting provisions (further indicators of vibration and shock resistance).

- Electronic and mechanical component counts (indicators of reliability, maintainability, and cost of logistics support).

These data items should be consistent with each other and with supplier claims. Inconsistencies indicate risks and may expose unreliable data that should not be used in system planning. Incomplete data may be an indication of maintaining security for proprietary data, tuning data to look better than it should, sloppiness in the data preparation, or honest omissions; the supplier may also be lying. Comparative data between products may use industry benchmarks but be based on "apples and oranges" tests, such as comparing the SPECint92/SPECint92fp performance between competing computers but including secondary cache on one but not the other. Other data may be gathered under unknown conditions, so the utility for making decisions is limited. Some commercial markets simply do not require many types of documentation common to military systems. In any case, incompleteness also indicates risks. Where documentation is not available, the information still needs to be developed. The last resort is the screening test.

For software, the screen is equivalent in form, but the issues are different. The same basic data elements are gathered from the same types of sources (specifications, test reports, quality data, etc.) but the form of the data and expertise needed to interpret the data is different from hardware products. The software must reside in a hardware environment, and comparative data from different sources usually do not provide information from the same environment. Even if they do, the data is

probably for an environment substantially different from that contemplated by the system designers. Third-party evaluations can also contain unknown, unintended biases. For instance, independent evaluations of three popular word processors by six different sources over a 4-month period resulted in six different rank-orders—all of the possible results. On the surface, each evaluation was looking at the same factors and using a common methodology. In practice, the results were being skewed by the different test tasks and the familiarity of the evaluators with one approach versus another.

Another software issue arises from the sharing of hardware resources with other software processes. Conflicts between applications can and do arise and can result in acceptable degradation of the speed of execution to system crashes. Most of these type of issues cannot be resolved by market survey and literature search results; they can only be resolved through testing.

Screening tests for software are essential, but they can range from simple demonstrations to complex tests similar in scope to full qualification tests. In any case, a common set of metrics should be used for the evaluations that are tailored to the intended applications and consistent throughout the system environment. The metrics should be stated in "application process units" (APU) that describe real processes functionally present in the system. SPECint92 and similar benchmark systems are defined at a lower level of functionality. APU measures should be defined in ways meaningful to the system users. While it may require considerable effort to define APU metrics, they can be used throughout the system life and are highly beneficial to the field user when upgrades are provided with APU benchmarks. Software screens should be done in a common hardware environment— ideally the same environment that will be present in the fielded system. When the hardware platforms are still undergoing selection, a common test environment that closely simulates the expected system can be acceptable.

The screening test is tailored to develop information that is otherwise missing and to validate that critical requirements can be met. Samples of the candidate NDI surviving to this stage are obtained for testing. At least three samples of each candidate is desired, although one is often all that can be obtained. Fewer than three test samples simply increases the risks associated with the validation function, so an actual "certificate of validation" may be delayed until after the system is in production. In any case, the tests should include the following steps for hardware and hardware/software products:

1. Initial performance tests to the manufacturer's specifications; where several parameters interact, choose "worst-case" test conditions.

2. Testing to project specifications, including environmental limits.

3. Burn-in for 100 clock hours (on each item).

4. Combined environment stress test including temperature, humidity, vibration, and electrical transients plus stresses from environmental cycling, EMI, and repetitive shock, as appropriate.

The combined environment test normally requires 120 hours. The entire test cycle can be completed in 3 weeks. With suitable environmental test equipment, all of the candidates can be done in parallel. Of course, the total calendar time required may be extended by excessive failures, by repair time, or by facility scheduling problems. The screening acceptance criteria are as follows:

1. No repeatable failures for any single test sequence. (For example, failure of a vibration test twice is not acceptable.)

2. No pattern failures (two or more failures of the same part in equivalent applications caused by the same failure mechanism.) Passing requires failure-free performance through the combined environment testing phase on at least one out of three trials; high-reliability items should pass in a single trial.

3. Measured MTBF meets or exceeds project requirements with acceptable confidence.

4. Predicted performance remains within required limits when weighed by quality factors.

5. Supplier claims for performance and quality are verified within acceptable limits. (Large variations between products and deviations from supplier claims make the overall product quality questionable.)

6. Overall conformance to program requirements.

Ideally, all of the candidates will be qualified without reservation. Usually, some candidates will be eliminated, and others will be identified as requiring modification. The candidates passed without reservation plus those candidates that require only minor modifications constitute the surviving pool of candidate NDI for use in the system. If there are no survivors, proceed with the system partitioning for another two levels of complexity and repeat the process. The additional system design exposes lower level standards and their associated NDI representatives. Generally, the entire screening process is conducted in concert with the system partitioning activities and does not add to the overall project schedule. However, some systems may require substantial amounts of testing, which must be planned and funded. Nevertheless, the exercise of screening tests develops valuable information that is useful for designers even when no candidates survive. Validating NDI candidates can greatly shorten the overall acquisition cycle and provide substantial cost savings that exceed the costs of screening by many orders of magnitude.

There are several times when screening tests might be conducted. The tailored screen and the market analysis are intimately linked, so this is often a time for conducting some tests and occurs prior to entering a procurement decision. Test samples for these tests must be procured or obtained via some access agreement such as a Cooperative Research And Development Agreement (CRADA). Once a procurement decision has been reached, tailored screen tests are often used to fill in information gaps needed to continue system planning. These tests may be conducted as part of the procurement and may include contractor demonstrations. Tests may also be required after system fielding to evaluate product improvements; test samples can be required as part of the initial procurement or through the CRADA vehicle.

Screening processes are applied for the initial acquisition of systems or of system components. An often-neglected acquisition issue is the need to acquire replacement spares and to certify improved products—hardware, software, and supporting training products. Since screening processes emphasize interface requirements and specifications, tailored screens can be employed throughout the system life to maintain the integrity of the system components. It is often necessary to maintain some form of market surveillance for potential spares throughout the system life. The market surveillance, spares screening, and configuration status accounting efforts must interact with each other and should be coordinated by the same organization—usually the Life-Cycle Management Activity.

Throughout the screening process, and especially in conjunction with the market analyses and surveys, it is essential to incorporate the best technical expertise available. This technical expertise

must be knowledgeable in the state of the art, in the market players, the technology players, the evolving standards, and the directions technology is likely to move. Not surprisingly, one individual can seldom cover all of these issues—a team must usually be assembled. It is also important to incorporate good operational expertise to help to resolve the user-maintainer requirements. The government laboratory is chartered to be the prime resource of this "smart buyer" expertise.

Technical Document 108 provides additional information on Screening Techniques and making Build, Buy, or Modify decisions. The screens should be structured to be conducted quickly (1 to 3 months) in order to ensure relevance of the screen results in subsequent procurements.

CONTRACTING FOR NDI

NDI should be procured using fixed-price contracts. Since the items already exist, there is no developmental risk. Even for Integrated NDI or Major Modifications of NDI, the scope of the efforts for integration or modification are limited. An acquisition that has so much risk that a fixed-price contract should not be used is also beyond the scope of the definitions of NDI.

Fixed-price contracting should be characterized by several features in contrast to the cost contracts normally used for the acquisition of items requiring development. These features include the following:

- Well-defined product requirements.
- Stable product requirements.
- Well-defined evaluation and acceptance criteria.
- Well-defined test criteria.
- Well-defined support criteria.
- Acceptably low risk to both the acquirer and the supplier.

Notice the common theme in these characterizations—WELL DEFINED. It may require considerable effort to make an acquisition well defined, especially when system requirements are fluid.

Special issues arise when contracting with foreign entities. These may include rights to data, translation of documentation into English, accessibility to spares and reprocurement rights, availability of contractor technical services, and rights to product improvements. There may also be questions about the proper interpretation of requirements, especially those that are hard to translate. This may also imply special testing that would not be required of domestic sources of supply. Many times, these issues are resolved by the foreign bidder by teaming with a domestic source. However, even when a domestic source is involved, the acquiring agency must verify that these issues are resolved.

The structure and legal ramifications of fixed-price contracts require that contract specifications be feasible and that the statement of work requirements be so well defined that independent estimates will agree closely with bidder estimates. The item's support should be acquired at the same time; therefore the support requirements should be well integrated into the specifications and SOW. Often, the item's support will take advantage of commercial warranties; however, there may be special

requirements that must be implemented to keep the commercial warranty valid. Each of the different types of NDI has special or peculiar elements that need to be incorporated into the contract requirements in some way. These issues are discussed in the sections that follow.

WRITING SPECIFICATIONS

Specifications provide the means of documenting and communicating technical requirements. There are many different kinds of technical requirements, just as there are many levels of complexity in any system. Reasons for documenting and communicating requirements include procurement, guiding development, transition of responsibilities between agencies (as between a developer and a Software Support Activity or In-service Engineering Agent), documenting interfaces for potential system upgrades or modifications, and documenting information for future use by users, maintainers, and repair agents. Each of these purposes tends to produce specifications with their own special requirements for the writer. Specifications for NDI acquisitions do not differ significantly from developmental acquisitions except for procurements. NDI procurement specifications have special characteristics to satisfy contracting needs, market needs, system design needs, and future support needs.

System specifications are often vague with many "To Be Determined" (TBD) requirements in some sections while being overly rigorous in others. This is a natural (and acceptable) element of developmental acquisitions, but it is unacceptable for procuring NDI. Developmental efforts will include efforts to define requirements sufficiently in the SOW; these efforts must precede an NDI acquisition effort or be included in the contracting plan. In fact, the thrust of the specification for NDI differs significantly from that of a development or from the system specifications. Many of the requirements for NDI specifications are consistent with DoD policies for performance-based specifications and for the preference of commercial standards over military-unique standards. Most programs require multiple specification types; too many NDI-based programs skip the step of generating a system specification and proceed directly to the NDI procurement specification. This will result in a lack of documentation of system-level support requirements that need to be integrated and maintained with the system. Table 1 identifies some of the significant differences between these three types of specifications.

Notice that the NDI specification requires a substantial amount of interpretation of operational requirements in order to generate the product-oriented technical requirements. This is the primary contribution of the system partitioning effort to the generation of NDI specifications. Many of the decisions made during the system partitioning for an NDI acquisition would be deferred in a development acquisition to a later design phase. In the NDI acquisition, coordination of the draft specification with industry can serve many of the same functions as the design phases in a development with regard to defining specifications. Several draft reviews may be required for complex systems. In addition to these characteristics, specifications for NDI must be sensitive to the type or types of NDI to be supported by the specification. See table 2.

Table 1. Differences between specification types.

System Specification	NDI Specification	Development Specification
Operational requirements oriented	Product requirements oriented (i.e., procurement oriented)	Technical requirements oriented (i.e., design oriented)
Technical requirement goals specified within acceptable ranges	Minimum requirements for acceptance specified	Minimum requirements for acceptance specified
"Minimum acceptable" means "what is needed to meet operational goals."	"Minimum acceptable" means "the lowest value that will not be rejected" and includes technical risk allowances to ensure meeting operational goals.	"Minimum acceptable" means "the lowest value that will not be rejected" and includes technical risk allowances to ensure meeting operational goals.
Technical parameters subject to tradeoff	Technical parameters strictly required	Technical parameters subject to tradeoff within well-defined criteria
Performance requirements are stated in operational terms.	Performance requirements are stated in technical terms.	Performance requirements are stated in technical terms plus operational tradeoff criteria.
Performance equals mission capability.	Performance stated in "form, fit, and function" terms	Performance stated in "form, fit, and function" terms plus some "how to" terms for implementing advanced development features
Quality requirements are in Test and Evaluation Master Plan (TEMP).	Quality requirements are process oriented with minimum (but rigorous) inspection and test.	Quality requirements are product oriented with emphasis on inspection and test.
Human Factors and Safety constraints identified	Human Factors and Safety requirements identified generally (i.e., "good enough"). Some system requirements may be addressed in system integration and separately from the NDI specification.	Human Factors and Safety requirements identified in detail
Support requirements and constraints are explicitly identified and direct support plans.	Support requirements are only in SOW—not in specification.	Support constraints are specified; support requirements are in Integrated Logistics Support Plans and SOW.

Table 2. NDI specification approaches.

NDI Type	Specification Approach
COTS, ROTS, etc.	Sufficient detail for purchasing (Commercial Item Description [CID]). Additional system requirements may be documented in the system specifications or in separate interface specifications.
MILOTS, FME	Use existing government (performance) specifications, but tailor quality conformance provisions for current acquisition. Separate application-specific interface specifications and system sustainability specifications may be needed.
MOTS	Two specifications: (1) purchase description for unmodified item and (2) process and/or interface specification for executing the modification. Added information for special quality requirements may be in SOW.
Integration NDI	System specification tailored to meet NDI acquisition criteria. May be supported by additional purchase descriptions for off-the-shelf items and process/interface specifications for any modifications.
Off-the-Shelf Full System (system is not pre-partitioned)	Operational requirements are restated as User Specifications, including full functional descriptions, environmental profiles, and interface specifications. Suppliers are allowed to generate technical approaches in response. (Acquirer must include extensive analysis of technical approach in source selection.)

The most critical problem in developing good NDI specifications is resolving unknown and vague requirements prior to using the specification for procurement. In a developmental acquisition, most of the resolution of these issues is through engineering analysis, prototyping, and testing. These activities may be required for NDI acquisitions, but NDI has more effective means available because the products already exist. These means include

- market analysis,
- supplier commenting, and
- screening tests.

The market analysis fills in many of the requirements that would normally be deferred until the system design had progressed to a sufficiently detailed level to expose the interface issues. These types of requirements tend to be TBDs in most system specifications because the detailed design work is performed by the developer rather than the system specifier. The market analysis will also reveal information helpful in performing the system partitioning, so the effort actually is less than the normal engineering analysis efforts needed to resolve the same details in a developmental effort. As draft specifications become available, they can be issued for industry comment. Industry commenting accomplishes several things at once:

1. known specifications can be commented upon for realism, doability, and potential cost impact,
2. the requirements can be verified for comprehensibility, completeness, and clarity, and
3. realistic targets can be identified for the TBD specifications.

Issuing the specifications for comment should be done through the contracting office, especially for the non-off-the-shelf items. This way, the contract files will have the information to satisfy the legal requirements for a fixed-price contract. When possible, screening tests can be conducted as either a part of the market analysis or as part of the proposal process rather than as part of acceptance testing.

The tests can be structured to identify any missing interface and support requirements. In addition to resolving the TBDs, the vague requirements, and other unknowns, the resulting specifications become well defined and well understood by the prospective suppliers. These conditions reduce costs and risks and increase the resultant system quality.

The various government specifications (Military Specifications, Federal Specifications, Military Standards, Federal Standards, and other agency standards) should be consulted but used with caution. For instance, the MIL-SPEC system of specifications, standards, and handbooks constitute the corporate memory of the DoD. These documents contain requirements, conditional requirements, desires, and good advice, but a requirement for one program may be only good advice for another. The conditional requirements are particularly troubling for both the acquisition agent and the supplier because they involve tradeoffs between performance issues, cost issues, risk issues, and schedule issues. These tradeoffs justify involving extensive technical and programmatic expertise in the specification writing process that can be carried into the dialog with industry in preparation for an acquisition. It is important to include expertise in a system design team highly conversant in the relevant government documents to sort out the issues raised. This is another of the roles of the "smart buyer" function played by a government laboratory. Current DoD policy is to cite industry standards rather than military specifications, and to include military requirements explicitly rather than by reference. However, this policy only addresses a small piece of the specification writing problem. The various government requirements documents do contain pertinent requirements, but these requirements usually require interpretation (tailoring) for use with NDI. The goal is to provide specifications in language easily interpreted by the suppliers, consistent with supplier/market practices, and granting suppliers the maximum latitude to meet the acquisition requirements with high-quality products.

All requirements originate with the system being designed. However, the system design intentionally adopts as many standards from pre-existing sources as possible. This promotes a long system design life, good system supportability, cost-effective system acquisition and support, the ability to use NDI, and multiple sources of system items and support. Procurement specifications for NDI should include all of the requirements essential to incorporate the items into the system design and nothing else. (Ideally, a simplified specification form called a Commercial Item Description [CID] can be used for most COTS.) There may be other system requirements, but these should be in other specifications. For any given item in the system design, there will be requirements unique to the military application of the system and requirements that are related to the technology being implemented in the system design. The military-unique requirements will be drawn from various military standards, such as MIL–STD–461 for electromagnetic compatibility issues (the military has many EMC issues that far exceed commercial EMC standards). However, military-unique requirements are best incorporated explicitly, where possible, and tailored to the specific system application. Incorporate requirements by reference only as a last resort, when the volume of information associated with the requirement is extensive even after tailoring the requirement. Commercial standards may be cited by reference, but they should still be tailored to the system application. System proprietary standards are all requirements not supported by an external reference standard. These requirements must be stated explicitly. Where the system proprietary requirements have been derived from engineering studies, it is a good idea to provide a reference to the source material. Use of an open architecture helps to separate the system specification issues from the NDI product procurement specification issues so that these specifications can each stand on their own.

A host of commercial and governmental standards are available from which to choose. The selection should be driven by the system partitioning decisions, but, all other things being equal, the order of preference should be as follows:

- DoD-adopted industry standards.
- International industry standards (ISO).
- National industry standards (ANSI).
- Industry-specific standards (IEEE, SAE, etc.).
- Federal standardization standards (FIPS, FED–STD).
- Federal interface and performance specifications (FED–SPEC).
- Agency-specific interface standards (MIL–STD).
- Agency-specific performance standards (MIL–SPEC).
- Agency-specific guidance (MIL–HDBK).
- System-specific specifications for existing MILOTS.
- System-specific specifications for existing FME.
- Market-driven specifications.
- Commercial proprietary specifications.

All other things usually are not equal. Also, the order of preference of selecting standards is not the same as the order of preference in considering NDI candidates (see **SYSTEM PARTITIONING FOR NDI**).

In 1989, this Center conducted an experiment in specifying NDI. The system requirement was for some specialized electronics gear to be used in the Persian Gulf Theater. Several different types of NDI existed to fulfill the system needs. The options included a full system (very expensive) requiring minor modifications that was available from a single source, COTS requiring some integration and many minor modifications from many commercial sources, ROTS requiring some integration but no modifications, and some MILOTS requiring minor modifications. Altogether, there were several dozen potential sources of supply. About half of these sources were strictly commercial, while the other half were companies routinely doing business with the military. The Center prepared two specification packages—one for the commercial market and one for the military market. The commercial market specification contained no references to external specifications or standards; all of the requirements were heavily tailored and highly explicit. The military market specification referenced many military and industry specifications, but each reference was heavily tailored to ensure that the actual requirements were consistent between both packages. The packages were broadcast in separate announcements to result in separate proposals with the caveat that either procurement might be canceled. We requested specification comments and very preliminary cost proposals for planning purposes. After receiving initial proposals, we conducted a bidder's conference. There were actually separate doors representing each announcement, but they led to a common room. Commercial responders to the commercial market specification provided cost estimates averaging 25 percent below the military market responders to the commercial specification. Military market responders to the military market specification provided cost estimates averaging about 25 percent below the commercial sources responding to the military market specification. The technical responses and cost estimates were consistent between the two lower tier and the two upper tier responses that resulted.

In other words, the value of the technology to meet the requirements was the same in each market, but there was also a cost premium for the perceived risk of providing a product to a different market with which the company was unfamiliar. This was particularly noticeable with companies responding to both announcements. While the experiment constitutes a datum of one, it illustrates the importance of communicating requirements to a market in language tailored to that market.

Finally, specifications must sometimes incorporate some special enabling features for NDI support that would not usually be considered. The most common of these requirements is for various features to support warranty enforcement. One common feature is a time-totalizing meter to allow warranty time to be measured on usage hours rather than on calendar time. Another feature might be a lockout to prevent tampering inside a warranted item. Special packaging might be required to adapt the item to a new environment; however, the "what" elements are the requirements rather than the "how to" issues. The system designer must be aware of these factors and features to include appropriate requirements in the specifications.

Knowledge of the NDI issues, awareness of the markets, incorporating appropriate technical expertise in standing requirements and in the technologies, and diligence in attention to detail all contribute to good specifications for NDI acquisitions.

STATEMENT OF WORK (SOW) REQUIREMENTS

A statement of work describes the tasks to be performed by a supplier in the course of performing a contract. These tasks should be constructed to embody those requirements that are not covered in the specifications or in delivered data. The typical requirements associated with NDI deal with conducting additional analyses or tests to generate quality, reliability, or support information that is not needed by the normal product market. Other tasks may involve modifications to the product or delivered data to adjust for differences between the market for which the product was designed versus the application to which it is being adapted. Of course, additional requirements arise from the management of the contract, such as design reviews for Integration NDI. Whatever these tasks may be, the differences between the normal business practices of NDI suppliers and the normal practices of DoD contracting can be substantial. It is important to scope and phrase the task requirements such that adequate best industry practices are allowed while DoD contracting requirements are met. Deviations from standard practices will cost extra and can defeat some of the immediate schedule and cost benefits of NDI.

Wherever possible, use purchasing techniques and conduct modifications to NDI "in house" to the acquisition. Modifications may often be done on the final product or data after it has been accepted from the original supplier. The limitations to this approach arise when the modification would invalidate a warranty or when the modification is so intrinsically associated with the product manufacture that it must be done on the production line. However, modifications done after acceptance allow greater control and flexibility for future modifications that can be critical to applications with dynamic operational requirements.

Modifications to NDI must often be done during the production process. For example, consider the mundane problem of having the NDI painted the right color. Ideally, one would accept NDI with its original paint; however, the original paint may be international orange where a camouflage color scheme might be required. This circumstance justifies changing the manufacturer's processes if the supplier is willing to do so (many commercial suppliers will not change their production line unless

there are very substantial minimum orders greatly in excess of a typical acquisition program's needs). In these cases, appropriate tasks should be included in the SOW to ensure that the production process flow and quality levels are maintained.

Sometimes, additional tasks may be needed to provide added data for the acquisition agency's use or to condition the product for special application environments. The Navy has a standard policy of applying Environmental Stress Screens to NDI hardware and Application Stress Screens to NDS. Each acquisition must be assessed to determine if these screens should be done by the supplier or after delivery. If they are to be done by the supplier, the SOW must contain the tasking. If they are to be done by a test agent other than the supplier, SOW tasks my be required to keep warranties in effect or to fix material found to be discrepant.

Also, special problems with data acquisition may require added tasks in the SOW. See **DATA ACQUISITION**.

In any case, SOW requirements should be kept to a minimum and should be sensitive to the marketplace(s) of the viable sources of supply. Industry reviews of draft SOWs are very useful in avoiding cost driver requirements and in identifying issues that should be included or deleted. The industry review can also ensure that the SOW requirements are well defined and clearly stated for use by the suppliers.

DATA ACQUISITION

Data is information in a specific format. Although the dictionary may not agree, this definition works well in DoD contracting. The acquisition project needs **information**, but **data** is what is actually obtained. All data must be acquired in accordance with a Contract Data Requirements List (CDRL). The CDRL establishes both administrative requirements (delivery date, receiving activity, number of copies) and technical requirements (data content, preparation instructions, formats). The technical requirements are detailed in Data Item Descriptions (DID) referenced and tailored in the CDRL. This applies to all DoD acquisitions.

In NDI acquisitions, most (but not all) of the information will already exist; however, many of the information items may be proprietary or in a form that is not suitable for the current acquisition. How the data is acquired can severely affect the contract price. Inappropriate data acquisition measures in NDI acquisitions have resulted in data packages costing as much as 90 percent of the full acquisition price. A determination must be made as to the most cost-effective means of obtaining information that does not currently exist. Usually, some form of tailored screening test will become the most inexpensive approach. The general rules in acquiring data all apply, but some special considerations for NDI acquisitions also apply.

In general, buy only the minimum essential data in its naturally occurring formats. In buying NDI, the formats will be predetermined for virtually all data. This is in contrast to developmental acquisitions, where much data is being developed as the product is being developed and where the desired format can be used as the data is developed. In developmental acquisitions, the format required for end use of the information is commonly specified for the data; this can have expensive consequences in NDI acquisitions. Furthermore, COTS acquisitions may encounter proprietary rights in data that may make it impractical to acquire certain data elements. However, just because information may be proprietary does not mean that it cannot be acquired. The desired information may be proprietary in

one form and not in another because of its association with other information in certain data formats. Also, certain data proprietary items may be available at a reasonable cost but with disclosure restrictions. As a result, data format can be a primary driver of data costs. For NDI acquisitions, data formats have already been set by the market, so deviations from these formats will always increase costs without changing the content of the information that is desired. Following these general data acquisition steps will help to ensure that all of the information is obtained in the most cost-effective manner:

1. Establish the information requirements of the acquisition.

2. Determine the end uses of the information, noting where one information element may be used for several end uses. (It is useful to establish a matrix of information elements and end-use elements in order to quickly visualize these relationships.)

3. Determine which information elements already exist and note the data form for each element.

4. Specify the end-use format requirements, maintaining as much flexibility in format as possible.

5. Determine modifications to existing data that may be required to make the information usable in the required end use.

6. Establish tasks for developing data for information elements that do not currently exist.

7. Establish approaches for obtaining existing data.

8. Draft the CDRL package, obtaining industry comment when appropriate.

Given the importance of data to the life-cycle support of a system, these steps should receive as much attention, care, and expertise as the generation of specifications.

Accurately determining the information requirements is usually the most challenging of all these steps for any acquisition. The following information elements are not meant to be all inclusive; however, this list may prove helpful to identify data that might otherwise be overlooked. Please note that most of these information elements are available within the government rather than from the supplier.

User Requirements Information

        Operational Requirements
        Operational Doctrine
        Operational Support Concepts
        User Skills
        Maintainer Skills
        User Interface Standards

Performance Information

        Application Performance Conformance
            Quality Data
            Inspection Data
            Field Data
            Test Data
        Environmental Conformance
            Analysis Data
            Field Data
            Test Data

Electromagnetic Compatibility Conformance
Field Data
Test Data

Safety Certifications

Analysis Data
Test Data

Supportability Information

Integrated Logistics Support Plan (ILSP) [and subsidiary support plans]
Failure Data
Maintenance Data
Warranty Data
Repair Item Cost Data
Technical Manuals
Operator Manuals
Training Data
Facilities Management Data

Installation Information

Interface Control Data
Installation Control Data
Installation and Checkout Procedures

Life-Cycle Control Information

Interface Standards (at each level of complexity)
Design Control Data
Production Control Data
Modification **and Upgrade** Control Data
Configuration Management Data

Project Management Information

Design Review Information
Project Metrics
Requirements
Quality/Defects
Reliability
Technical Performance and Design Characterization
Productivity
Project Performance (cost and schedule)
Project Administrative Information
Progress
Financial
Work Breakdown and Tasking Information

Most of the information needed for a project is not obtained from the product supplier. Most of the data requirements are for use internal to the government (and mostly within the requiring agency), and most of the information elements are resident with the government, being the result of the requirements definition process or the decisions needed to assemble a procurement package. Therefore, the most cost-effective means of obtaining the information needed from the supplier is to

get existing data in its native formats and to extract or convert the information to the required format. If the information is available in digital form that can be transferred through a recognized standard, the conversion from supplier to government formats is even more efficient.

To promote the efficient sharing of information between industry and governmental entities, DoD has established the CALS initiatives. (CALS currently stands for Concurrent Acquisition and Life-Cycle Support. The definition of the CALS acronym has been changed several times, but the acronym has remained stable.) The CALS initiatives have adopted several formats for exchanging data. These include the Initial Graphics Exchange Specification (IGES) (a vector format for drawing information), the Joint Engineering Documentation Management Information Control System (JED-MICS) specification (a raster image format that is effectively a Tagged Image File Format (TIFF) with some added file header information), the Standard Graphics Markup Language (SGML) (a text plus graphics format that is a superset of the Hypertext Markup Language (HTML) used to create Internet web pages and of the Help Metafile Language used in many computer "help" and "tutorial" applications.), and the Computer Graphics Metafile (CGM) format (a vector and raster image format for computer presentation files). The CALS standards are widely accepted and used by industry, and commercial tools are available to translate between the various formats and to these formats from the various proprietary file formats used by the various computer tools that companies use to create and manage their products. Most companies doing business with DoD now support CALS; however, many of the small commercial businesses supplying COTS items do not have CALS tools. Where CALS tools do not exist, but the data is in digital form, almost any mutually agreeable format can be made to work. The most common include the popular printer/plotter languages (encapsulated post-script and the Hewlett Packard standard languages), for which tools exist to convert from these formats to CALS formats.

When preparing to receive data in digital form, it is an excellent idea to conduct test transfers of simple test patterns that contain one each of all of the digital entities that will make up the data files to be delivered. This is because the digital data is usually being translated out of a proprietary format into the specified export format. The implementation of the data translators may be incomplete. Also, there can be various "flavors" of the commercial standards that might be involved that will have subtle and incompatible variations. Some of these incompatibilities will cause some of the digital data to be lost or corrupted. The test transfers can discover any problems that might exist and allow workarounds and fixes to be identified. Sometimes the information will be slightly reformatted (text fonts might be changed, for instance); other times the information will be unreadable. Generally, as long as the information is readable and intact, it will be acceptable.

A much more serious problem arises when the supplier information is created for a market that is fundamentally incompatible with the intended application. The most common instance occurs when the commercial item is intended for specially trained and highly skilled technicians, but the intended application is being supported by junior field technicians. In these circumstances, the commercial technical manuals are likely to be written at several reading grade levels above the service standard. If more than **10 percent** of a commercial data item must be rewritten or converted to be compatible with the intended application, then the entire item should be rewritten. If only minor modifications are required, a data supplement can be generated to incorporate the needed changes; however, it is important to ensure that the information flow and continuity of the data item is not disrupted when a supplement is employed. This may mean that added information might be included in the data supplement to retain the information continuity. Rewriting technical manuals can be very expensive, but the operators and maintainers must be viewed as part of the overall system. The most effective means of communicating system technical information to operators and maintainers should be

considered in the system planning and integration and should consider total life-cycle costs. Since personnel are high-turnover elements of the system, the costs of communicating technical information to them through technical manuals and training become very significant. Technical manual costs are relatively fixed while training costs are recurring costs, so life-cycle cost decisions tend to favor good technical manuals.

Many types of information need to be incorporated into system planning. Much of this information is found in different forms for NDI in contrast to developmental acquisitions. The data for COTS items is formatted for commercial uses by users of variable sophistication. Developmental acquisition data is usually created in the format in which it will be used. Much of the system support information must be obtained from suppliers of NDI but reformatted for use in the DoD support system. In addition, the quality of the information from the various NDI sources may be questionable. The confidence levels associated with quality and reliability information from NDI sources may be different from that needed for a particular system application. These differences must be resolved in order to use the information appropriately. Tests are often required in order to develop sufficiently high confidence levels and to resolve information quality issues. The tests are usually incorporated into the tailored screens, but if they are not, they should be budgeted as part of the data acquisition effort.

When acquiring FME or FCOTS, be sure to plan for the time and expense of translating the information into English, if required. Also, ensure that specifications and other support information are available in English as well as the native language. Make sure that translation costs are identified for the procurements and also for the maintenance of technical documentation.

What is the most cost-effective means of obtaining high-quality information to support good system decisions? There are a variety of ways to obtain this information for NDI. For instance, to support a system deployed in a ship in the Indian Ocean is a substantially different problem from supporting the same system in San Diego, California. To achieve high levels of operational availability, the support planning must have good information on the product reliability and failure rates. One can conduct a reliability analysis of the design, conduct an analysis of field failure data, review warranty data, review supplier test data, conduct reliability qualification tests, or perform some combination of these methods. Generally, field data and warranty experience provide the highest confidence data, but the confidence in this data can be eroded by differences in application environments, lack of product maturity, and undisclosed methods of converting raw information into published data. If a COTS item was designed for use in home environments in San Diego, there is very low confidence in the field failure data for its use in support planning for a deployed shipboard application; nevertheless, the item may be perfectly acceptable for this application. An analysis of the design might give a qualitative confidence that it is sufficiently robust for use aboard ship, but the quantitative confidence levels in the information derived from such an analysis may require extra pipeline spares of an expensive end item in order to assure good operational availability. Testing may provide high-confidence information, but the test itself may be prohibitively expensive for a highly reliable item. This is especially true if the system is being acquired for only a few dozen installations. Also, supplier tests may be inadequately documented to determine their accuracy or applicability. (Some types of tests can be grossly affected by the test setup or test procedures so that reported performance is much better than what can be realized in the field. This is especially true of environmental tests such as impact shock and vibration.) The normal solution requires an integration of all of the available information together with screening tests. The screening tests are constructed to eliminate factors that degrade the confidence associated with other sources of information. This allows the tests to be constructed to be affordable but still allows decisions to be based on the best available

information. The goal is to use the available information to the maximum extent possible, supplementing it with newly developed information as needed to achieve confidence levels that are good enough. A good indication of "good enough" is when information from the different sources all agree within the acceptable uncertainties.

In general, at least as much effort must be put into acquiring good information as in acquiring the products. This is especially true of NDI acquisition. Bringing the appropriate expertise to bear in developing the information/data requirements and tailoring the information development activities is at least as important as applying good expertise to the system design and development of specifications. This problem is easier for NDI in the respect that so much more information can generally be made available. The problem is more difficult in that the data must be interpreted from its market perspective into the system application perspective. It is a good idea to submit draft versions of the CDRL to industry for comment to ensure that no unnecessary cost driver requirements are included. The CDRL and the referenced DIDs must be tailored carefully to obtain all of the information needed in acceptable and usable forms while allowing for the high degree of variability that may exist in the NDI market.

SOLICITATION AND SOURCE SELECTION TIPS

Source selection can be based on either **least overall cost** or **best-value** criteria. It is essential to determine which set of criteria is to be used and to develop appropriate supporting solicitation documentation.

When least overall cost criteria are used, the cost to the government is the primary determining factor in source selection, excluding candidates that are technically unacceptable. Often, only the bid price is used to determine costs, but only because other costs are left undetermined (because the bid cost is the only significant cost, because the other costs are not variable between bidders, or because the acquiring agency has neglected to develop appropriate tools for evaluating other costs). Other cost factors can be used. The two most common are Design-to-Cost (DTC) and Life-Cycle Cost (LCC). DTC criteria include the bid cost plus costs for acceptance and post-delivery requirements (such as installation and checkout and modifications). For most NDI acquisitions, acceptance and post-delivery costs are equal for all candidates, so the bid cost is the only significant determining factor. However, if NDI modifications are required, there may be significant differences in non-bid costs that should be accounted for in the source selection. LCC criteria evaluate the costs for the entire life of the system. Since there may be significant differences in quality and reliability between candidates, LCC criteria can make a substantial difference in the source selection from bid cost. However, to employ LCC criteria, a LCC model must be developed and validated. Failure to validate the model prior to its use will lead to protests by non-selected sources, particularly those who have a lower bid cost than the selected source. The validation of the cost model involves test applications to existing systems where the costs are known and well documented to show that the model accurately predicts the actual experience. The validation process is both lengthy and expensive, so LCC is seldom applied to NDI acquisitions unless a validated model already exists. Another problem with LCC arises because many usable models are forced by cost factors that are hard to determine prior to several years of field use. Such models are useful for reprocurements and support planning, but not for source selection. Nevertheless, LCC criteria are the best to use whenever least overall cost is appropriate for source selection.

The best least overall cost criteria for use in NDI acquisitions are Differential Life-Cycle Costs (DLCC). In DLCC, a simplified model is constructed that contains only those factors that can be affected by the supplier. These might include the bid cost, reliability/failure rate factors (affecting the cost-per-failure support costs), the reading grade level and effective page count of the technical manuals (affecting training costs or personnel factors), weight and power and special service requirements (affecting installation costs), quality factors (that affect the confidence applied to other planning numbers, and support costs. Any life-cycle factors that are not affected by elements under the supplier's control are computed to fixed factors (such as the life-cycle billet costs of users and maintainers). The proposal preparation instructions (Section L of the solicitation) will require the proposer to provide the data needed to run the model. Proposers should be required to provide information to substantiate the numbers provided for the DLCC. Since DLCC models are highly simplified compared to normal LCC models, they can be easily and quickly evaluated. The need to validate the model can be eliminated by soliciting industry comments when the specification, SOW, and CDRL are sent out for comment. Also, the DLCC model should be published as part of the evaluation criteria (Section M of the solicitation). DLCC is the recommended approach for NDI acquisitions when using least overall cost criteria.

Best-value criteria weigh technical factors more heavily than cost factors in the source selection. The criteria are applied in recognition that paying a little more for significant increases in performance, quality, and reliability can be greatly beneficial to the government. The simplest form of best value merely weighs the technical evaluation score 2, 3, or 4 times as heavily as the cost evaluation score. This is very useful for research and development proposals where there may be relatively small differences between cost proposals but clear differences in technical proposals. However, this approach does not accurately evaluate relative cost differences against technical differences, and it invites protests when there are large cost differences between acceptable proposers. It is not recommended for NDI acquisitions. Another best-value approach scores all proposers against the lowest cost acceptable proposal. In this approach, the source selected is the greatest weighted delta in technical score for the least weighted delta in cost. This approach does work well for NDI acquisitions, especially for the non-off-the-shelf alternatives.

Least overall cost criteria should be used whenever the candidates are true off-the-shelf (no modifications or integration by the supplier), mature (no NewCOTS), and competitive in the same market. Best-value criteria should be used whenever the candidates include NewCOTS, MILOTS available from several suppliers to performance specifications, mixtures between COTS/ROTS and MILOTS, or diverse markets. Much NDI can be acquired using purchasing techniques (applying least overall cost criteria). In practical terms for larger systems, least overall cost criteria are most usually desired, but best-value criteria are applied because it is impossible to determine ahead of time that all candidates will conform to the least overall cost strictures. Also, the high complexity of large systems tends to obscure performance factors, so a best-value approach is justified to provide a more thorough and fair treatment of the performance versus cost differentials.

A third best-value approach takes the phrase "most bang for the buck" quite literally. In this approach, the technical scores, corrected for evaluated risk, are converted to a standard quantitative score and divided by a differential life-cycle cost. The best features of best value and least overall cost criteria are both used in making the source selection. The highest resulting score is selected. It is unnecessary to disqualify bidders as the technical scores for unqualified bidders will be too low to be competitive. This method is relatively easy to use and always applicable to NDI acquisitions of all types. Although somewhat more labor intensive to establish, this approach works very well for

all forms of NDI. It is the preferred method for large, complex systems, for major modifications, and for Integrated NDI.

The solicitation is an ideal opportunity to obtain information. Some of the information that should be considered include the following elements:

- Performance characteristics, including specifications and standards, ranges of operation, physical properties, environmental performance, and installation characteristics.

- Supportability characteristics, including supplier support, repair costs, and upgrade characteristics.

- Test data, including results, data, methodology/procedures, standards, and setups.

- Quality data, including defect metrics, warranty data, scrap rates, rework rates, repair rates, repair turnaround rates, quality implementation plans, and customer compliments/complaints.

- Recommended lists of repair items and consumables, including range and depth of support.

- Recommended support and test equipment.

- Recommended plans to ensure availability of spares and surge capabilities in case of mobilization.

- Identification of proprietary rights, limited rights in data, and patent rights.

- Recommended documentation, manuals, and training materials.

- Proposed training support.

- Proposed warranty provisions, restrictions, costs, and procedures.

- Health and safety certifications.

- Availability of contractor engineering technical services.

- Information required for the evaluations (Section L).

- Alternative proposals.

Some of this information can be obtained during market surveys, through "sources sought" solicitations, and the process of gathering industry comments prior to a formal procurement solicitation. Other information may not be needed. Note that most of this information is related to the sustainability of the resulting system. The information may be required if the sustainability plans have options that can be negotiated during the procurement. If the decisions have been made so that no options exist, the data should be supplied in accordance with the CDRL. All of the information obtained needs to be assessed against the needs of the ultimate users and maintainers, especially the potential impact on availability of the system in a deployed status (see **SUPPORT PLANNING**).

TECHNICAL EVALUATION CRITERIA TIPS

A good technical evaluation is critical to any source selection for the procurement of complex items. Good evaluations are structured to maintain strict fairness to all, to thoroughly demonstrate the proposer's understanding of the requirements, to assess the capabilities to perform, and to document the information used to make the source selection. To support these goals, a number of best practices can be applied:

- Prioritize and segment the requirements into related groups.

- Form evaluation teams of technical experts for each requirements group.

- Use a technical evaluation form tailored to each criterion and set up to capture narrative evaluations of the strengths and weaknesses of each proposal. Evaluators should have to explain why the criterion is being graded a particular way.

- Instruct the proposers (Section L) to format the proposals consistently with the grouping of the requirements. (A separate proposal volume for each major requirements group.) Include a page count limitation, either by requirements group or overall.

- Include an assessment of the risk with each evaluation element.

- Provide descriptors of the evaluation grade levels that include quality of performance offered and risks that are non-ambiguous. Do not allow too many gradations of evaluation, but make clear distinctions between evaluation levels.

Evaluations and grading systems can be structured in many ways to accomplish the goals of the technical evaluation. A major key is to set up this structure so that it is easy for evaluators to be consistent in their assessments. Also, it is important to set up the requirements groupings so that they are comprehensive yet without too much detail that dilutes the efforts of either the proposers or the evaluators. A good approach here is to request the proposer to show how the proposed approach will meet a required figure of merit that describes some block of requirement capabilities. These tips apply whether the acquisition is NDI or not.

Because NDI is pre-existent, a technical evaluation may include several things that would not be possible for developmental acquisitions. These include the following:

- A live demonstration of the system capability (or some significant portion for integration NDI). This can include software running on hardware, live communications, set-up/tear-down demonstrations, and anything else identified as a key system capability. Real operational capabilities in real environments are desired in demonstrations, but the proposer must not be required to make unreasonable investments that cannot be compensated unless the contract is won. One approach is to conduct an initial evaluation to prescreen proposals, and then to pay a fixed fee to all qualified proposers to conduct a demonstration.

- Historical information that demonstrates the capability to perform at low risk. This can include quality and reliability information.

- Supplier process and procedure information that demonstrates both capability and maturity in performing the required tasks. This element is particularly critical for software requirements.

- Examination of actual technical data to be delivered, such as technical manuals, drawings, Interface Description Documents, etc. These documents are loaned for purposes of the evaluation and only delivered by the selectee.

Proposers of NDI should be encouraged to provide alternate proposals of new or upgraded products that may have been undisclosed to the market survey. The technical evaluation should evaluate these alternatives as if they were separate proposals, neither adding nor detracting from the proposers main proposal.

TESTING NDI

All acquisition programs must perform testing. Standard tests include operational evaluations, technical evaluations, production/factory acceptance tests, first article tests, quality conformance tests, workmanship screens, safety certification tests, and reliability/maintainability tests. There may also be human factors evaluations, and specialized tests for software, materials, processes, and parts. These tests evaluate the system and its components' ability to meet all of the system requirements. Of course, there are a variety of developmental tests within development acquisitions that do not apply to NDI acquisitions. All of the major forms of testing apply to NDI acquisitions, but the character of the tests may change. For instance, most production acceptance testing will conform to the accepted supplier practices for COTS/ROTS rather than being specified in procurement specifications. On the other hand, special screens and documentary tests may be required in an NDI acquisition that would not be encountered in developmental acquisitions. Also, special tests may be required for certain types of NDI and not for others. Most of the test issues associated with NDI are summarized in table 3.

Table 3. Test and evaluation summary.

Test Requirement	NDI Advice or Requirement
Operational Evaluation (OPEVAL)	Required prior to Milestone 3. May be combined with source selection process with appropriate planning for true _OTS systems. Added time required for non_OTS systems.
Technical Evaluation (TECHEVAL)	Required prior to OPEVAL. Should be combined with source selection process where possible. (Do not confuse TECHEVAL with the technical evaluation conducted as part of the source selection process.)
First Article Tests	Only required when there is a true first article—especially for MILOTS, NewCOTS, major modifications, and integrated NDI. Should also be applied for NDS and most modifications.
Production Acceptance Tests	Normally not required beyond established and accepted supplier production tests, except for MILOTS. (Test protocols can be reviewed and accepted in accordance with ISO9000 series practices.) May be required for some integrated NDI and some major modifications. May be required for limited duration on productions of NewCOTS.
Quality Conformance Tests	Normally not required except for some MILOTS, Integrated NDI, and some major modifications.
Workmanship Screens	Normally Environmental Stress Screening required for hardware items being subjected to a more severe environment than that for which the equipment was originally designed and produced. This includes most Navy shipboard environments. May be applied for applications requiring especially high reliability. May be required for NewCOTS.
Foreign Capability Evaluation	Applied to FME and FCOTS items as a form of market survey screen. May be used to equalize foreign candidates with domestic candidates for source selection purposes.
Supplier Demonstration Tests	Used as part of the technical evaluation portion of the source selection process, where applicable.
Interoperability Tests	Required at each system level of complexity. Integrated at the top levels with TECHEVAL and other system tests. Needed at lower levels to maintain surveillance of interface performance throughout the system life. Conducted to the configuration item level.

Table 3. Test and evaluation summary. (Continued)

Test Requirement	NDI Advice or Requirement
Human Factors Demonstrations	May be performed during the market survey or during the source selection process. Should be required for all systems having a significant or new operator interface requirement and all systems having complex maintenance tasks.
Safety Certification Tests	Normally conducted by the supplier for NDI. May be required for integrated NDI.
Reliability Tests	Reliability Screen may be required to supplement other available information and to increase confidence in reliability data for making support decisions.
Maintainability Demonstrations	Not normally required for NDI, but may be required in preparation for OPEVAL for maintenance-intensive systems at the organizational level and for vital system verification of operational availability requirements.
Materials Tests	Not required unless new materials are being introduced or material substitutions have been made to modify NDI to meet application requirements and the substituted materials have not been previously qualified.
Process Tests	Suggested when quality and reliability requirements are high and new processes are introduced. Normally conducted by supplier with notification to acquirer under ISO9000 series procedures. May be required/negotiated for some NDS acquisitions.
Parts Tests	Conducted by supplier as required. No notification required to acquirer.
NDI Screening Tests	Should be conducted as part of market survey to close gaps between market requirements and standards and military application requirements. Usually involve combined environment testing (especially shock, vibration, temperature, and humidity), electromagnetic compatibility testing (including power system interfaces), and special performance requirements. Tests may also be conducted to develop interface control information outside of existing interface standards.
Capability Demonstration	May be required as a part of the source selection process for true NDI elements. May vary from a full system demonstration in operational environments to demonstrations of key subsystem items at supplier's facilities. Consider feasibility of combining other program tests (such as OPEVAL and TECHEVAL) into the demonstration.
Regression Tests	Normally required for revised NDS, conducted by acquirer's Software Support Activity.

Please note that table 3 is not intended to be exhaustive; however, it covers the most commonly encountered tests. A competent system test director should be employed on the acquisition team to determine any special test requirements as well as to tailor individual test requirements, review supplier test documentation, witness supplier tests, and supply advice to the project manager on test issues.

RELIABILITY ISSUES

Three levels of reliability must be considered and reconciled for any acquisition: system, product, and component. Because of the character of NDI, the emphasis tends to shift from component reliability (high emphasis in developments) to system reliability. Good system design practices will incorporate reliability issues in meeting the operational requirements, but NDI acquisitions also require many of the solutions to be accomplished at the system level as well. This is because the system designer is "stuck" with the product and component reliability of the NDI once a source selection is made. The goal of the reliability program remains to maximize both operational availability and dependability for the system users.

Component reliability emphasizes the selection of high-quality components, good thermal design practices, good derating practices, and avoiding/mitigating known component failure modes throughout the product design. NDI projects do not have control over these elements; however, that does not prevent the system reliability experts from evaluating the design of the products. A quick scan of the product design documentation will often reveal the integrity of the product design in its application of the components While this information may not be sufficient to establish support plans, it can be crucial to resolving the confidence levels of information from other sources and in identifying potential problems.

Many MIL development programs result in low-volume productions. This means that they depend on increasing the component application reliability levels through parts control programs and other means. MILOTS and FME items should have extensive component application information available for review. Most COTS, ROTS, and FCOTS use industrial best practices and do not emphasize component reliability. Reliability issues are resolved at the product level through continuous product improvements. For instance, the higher production rates of COTS items usually justify the use of application specific integrated circuit (ASIC) technology, and other inherently reliable technologies, that may not be affordable to many MIL applications. COTS suppliers have an economic incentive to make their products reliable. Low product reliability will cut profits and market share. Mature COTS products will have good field data to support the reliability assessments; however, NewCOTS will lack this information. A more detailed component-level reliability assessment is warranted for NewCOTS.

Integrated NDI and modifications should normally have component-level application guidelines (and software development plans [SDP], as appropriate) to promote good system reliability when all of the system elements are integrated together. Unlike development programs, integrated NDI need not have extensive reliability analyses and reviews as long as the approved guidelines are mutually accepted and implemented by the supplier and acquirer.

Product reliability is driven by the component application reliability, by production quality, and by economic tradeoffs between initial costs and life-cycle support costs. Since most commercial items have a very short product life (5 to 6 years is typical) compared to military system lives (typically 20 to 30 years), the reliability factors driving life-cycle support costs are not as important in this trade-off. This is not to say that COTS items are inherently less reliable than "equivalent" military items. In fact, the opposite has been found to be true in the majority of studies comparing like products from these diverse cultures. Most "militarized" products lack sufficient production requirements to even begin to resolve all of the production process elements that improve product quality and reliability, and component reliability can seldom be maximized. Commercial items achieve component reliabilities an order of magnitude less than most military items, yet the commercial products may

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have a product reliability several times higher than the military product. The primary difference is the contribution of high-volume production processes that compensate for the lack of component reliability. Some commercial markets have a very high reliability requirement (medical electronics, for instance) and employ high-reliability components in combination with high-quality processes to produce products at extremely high reliability levels (comparable to space qualified systems).

System reliability rests on product reliability plus the system architecture/system partitioning decisions. Highly reliable systems can be constructed from basically unreliable pieces, at a price, if the underlying reliabilities can be adequately characterized. High system reliability is essential to highly effective and affordable operational availability and dependability. On the other hand, poor system designs have implemented low levels of reliability even though component reliability was maximized. In NDI systems, system reliability design is crucial. Since the product/component reliabilities are fixed, the system level is the only place that there is flexibility to meet the operational reliability objectives.

A major problem for the system reliability designer is the lack of high-confidence information on the NDI components. The reliability must be allocated from the system level to the subsidiary levels in a way that the allocated reliability is compatible with the realized product reliability at that level. For a given NDI, there may be an order of magnitude difference in failure rates between the low-end and top-end suppliers. Furthermore, field failure rate data, test data, warranty data, and analysis predictions may disagree by a factor of 10. Such large variations are intolerable for support planning purposes unless all of the data indicates a reliability substantially higher than the expected service life of the product, and the product population is relatively small. The system designer must realize that none of these sources of information is "wrong" but that the variations are artifacts of the low confidence levels that are sometimes associated with the various sources. Some effort is required to resolve the problems created by the low confidence levels that may involve added market investigations and testing.

How does the system designer deal with this problem? Field data (including warranty data) is generally the highest confidence level of all sources of data; however, this is not true for immature or low-population systems, such as NewCOTS and many MILOTS and FME. Field data may also be for application environments that do not accurately reflect the stresses of the new system application, and adjustments between the environments may have a low confidence in themselves. Nevertheless, field data is used as a source of preference when the product being considered is mature. Testing is the next most reliable source; however, high-reliability systems virtually preclude sufficient testing programs to generate reliable, high-confidence data. Fortunately, field data and test data can often be combined for analysis purposes under the right conditions. If the testing is conducted to stress the product with a combined environment meeting or exceeding the intended application, the resulting failures can be analyzed to determine if any new failure modes have been exposed due to the environmental stress, and the added test time can be combined with known field use time. In addition, a thermal survey can be added to the testing; the thermal survey is a quick and inexpensive test that provides a high degree of information about the reliability design and field performance of the equipment. Similarly, stress testing software can yield valuable information that can verify other sources of information and help to raise the confidence to acceptable levels. Reliability predictions are the least reliable source of information by themselves; however, they can contribute significantly to resolving data differences between field data extracted from different sources or from different application environments. Also, predictions can give valuable insights into potential disagreements between field data and test data. Predictions are quite useful in determining how much test time may be required to resolve confidence levels. Since test time is costly, the predictions may be essential

for project planning with sufficient lead time to obtain the needed resources. Finally, predictions are often helpful in giving indicators about the effects of production quality. If there are substantial differences between two sources of supply in quality, there should be an observable difference in field reliability that should agree with predictions within a factor of two. It is useful for the system designer to obtain as much data from potential suppliers as possible, including the supplier's predictions. Each source of information adds a perspective and fills in a piece of the overall puzzle. A bit of information may not be of high confidence in itself nor answer the ultimate system reliability questions, but the accumulated bits allow the system designer to get good enough information in total to continue the system planning with confidence.

One of the critical issues of system reliability design is the single point failure (SPF). In general, system designers try to avoid SPFs. Even if one is successful in constructing a top-level architecture avoiding single points of failure, lower level SPFs can be introduced by NDI components. This is especially true when the item was designed for a benign commercial application but is being applied to a mission-critical application. Awareness of the SPF can allow the system designer to employ high-level redundancy, automatic backup, or operational sparing to achieve the requisite levels of system reliability and availability. Among the crucial elements to be considered are power supplies. Power supplies are often SPFs for developed systems, but they are almost always SPFs in COTS systems. System designer, beware!

During the system partitioning/market survey, the system designer should obtain the following information elements, as a minimum, if possible:

- The supplier reliability design program (not merely marketing brochure claims, but documented evidence), including derating criteria, thermal analyses, predictions, and shock/vibration analysis.

- Product MTBF based on field/warranty data.

- Target design environment for the product.

- Failure Modes, Effects, and Criticality Analysis results.

- Employment of Environmental Stress Screening, part selection/qualification programs, critical part inspections, and other workmanship/quality provisions.

- System and subsystem reliability testing (procedures and results).

The reliability design is heavily interdependent with the supplier quality practices. An excellent reliability design can be compromised by poor quality practices. Excellent quality practices can partially compensate for a poor reliability design. Ideally, an excellent reliability design will be implemented with an excellent quality program as well.

OVERALL SYSTEM RELIABILITY ISSUES

While most reliability issues have traditionally rested on hardware failure modes and effects, systems consist of hardware, software, and operators/maintainers in interaction with each other. Therefore, system reliability must consider all of these factors both independently and in combination.

Hardware reliability issues are primarily driven by physical factors. Understanding the physics of failure allows suitable steps to be taken in system design, product design, production, quality control, process selection, material selection, and so forth, to achieve very high levels of reliability in the

most rigorous levels of application stress. Traditional reliability disciplines and tools aid in accomplishing high reliability in an affordable way.

Software has increasingly assumed greater burdens of system functionality. Since software does not have a true physical nature, it is not subject to failure in the same sense as hardware. Nevertheless, software may contain latent defects, may be executed in unintended ways when interacting with other software or hardware elements, or may not be designed to deal with hardware faults and human errors. Ideally, software should be designed for all potential interface and error conditions as well as performing all intended functions perfectly. In practice, this is not usually possible even in the abstract because software, especially NDS and reuse software, will be used in applications and environments that could not have been anticipated by any designer. As it turns out, the conditions that lead to a software-driven system failure have a statistical behavior that is not too different from hardware failures, so the mathematics used at the system level for analyzing reliability is well understood. Considerable research has been conducted since the early 1980s (and continues) on software reliability issues. The key for the system designer is to obtain software development quality metrics and field quality metrics, to conduct rigorous software capability evaluations tailored to the intended application and computing environment with appropriate system stresses included, to construct appropriate application process unit metrics, and to conduct well-instrumented system integration/ system interoperability tests. While these elements should be found in any well-designed system acquisition, they are even more important in NDI acquisitions because the software products are pre-existent and must be characterized for the new system application. These steps in combination allow the development of an accurate picture of system behavior in the field, even when the fielded configurations are changing rapidly (a characteristic of NDI-based systems). A wide variety of models exist to assess software reliability and to combine the knowable information about the software being considered for inclusion in a system. These models allow the development of information critical to making support decisions, planning SSA funding levels, and performing the needed tests cost effectively.

The third component of system reliability is the human operator or maintainer. Humans are subject to making errors, especially under the stress of combat. Human error also has a random character that is similar in its statistics to hardware failures; therefore, system-level analysis tools exist to include human performance in overall system reliability. Not surprisingly, human operators are often found to be single point failures in system reliability analyses. The system designer must balance human factors design (see **HUMAN FACTORS**) and training requirements (see **TRAIN-ING**) in order to achieve high levels of system performance in the field at an affordable price. A key element of performing this task is the definition of meaningful metrics of human performance as a part of the system that can sense human stress conditions (such as combat performance or the frustration level after making an error or the confusion when presented with unexpected conditions). In NDI systems, the human factors and training elements are severely constrained, so the allocation of system failures must first consider these constraints, resulting in higher requirements for the software and hardware products.

The key to understanding all system reliability issues is to recognize that stresses promote failures. The stresses promoting failures are different for hardware, software, and humans, but the system designer can identify, analyze, and quantify these stresses. If the stresses are known, it is much easier to determine appropriate actions, such as redesign, reallocation of requirements, or encapsulation (isolating a system element from the stress), that result in affordable systems that perform adequately with acceptable operational risk. It is essential to obtain appropriate expertise to participate in these system reliability issues, especially as they bear on the market survey activities and screening

activities supporting the overall acquisition. This level of system expertise should be retained in the life-cycle management activities after the system is fielded in order to promote effective decisions in the replacement decisions made during the support of the system.

Usually, all of the factors needed to evaluate system performance do not occur until system integration tests or TECHEVAL. NDI acquisitions are often so short that no prior testing will be feasible prior to these high-level system tests; therefore, the acquiring agent should expect that some surprises will occur because the accumulated risk can be quite high at the system level. As long as these surprises are anticipated and the tests are instrumented with appropriate measures of performance (for hardware, software, humans, and the total system) and some level of effort is planned (and funded) to handle minor contingencies, the project can proceed and attain success. All of these elements will be required in order to obtain high user satisfaction with the fielded system.

QUALITY PROVISIONS

Quality is the ability to meet requirements generated by implemented processes and procedures throughout the product life cycle (concept, design, production, and support). At least three different perspectives on quality can be combined to create an overall quality profile for NDI products; these are:

- Process assurance.
- Product assurance.
- Market assurance.

Process assurance focuses on maintaining excellent processes in the creation and management of a product with the underlying assumption that good processes create good products. This assumption is borne out by field experience. Product assurance imposes procedures to contribute to overall quality, such as inspections, tests, and audits. Many of the good processes chosen in a process assurance perspective will contain procedures from the product assurance perspective tailored to the process. Market assurance combines company practices with market dynamics to maintain a sufficient quality perspective to remain cost competitive and reputation competitive in a particular product market. Market assurance may adopt process assurance and product assurance practices, but it is also heavily influenced by competition factors in the marketplace. Each supplier maintains a different market assurance quality perspective, and this perspective may vary from product to product even by the same supplier. The various quality standards are an attempt to overcome the uncertainties associated with market assurance.

The ISO9000 series of quality standards represent a worldwide attempt to provide stability in product quality. This series emphasizes process assurance activities. There are procedures for obtaining an ISO9000 certification that testify that a supplier has formal quality processes in place that meet at least the minimum standards. In addition to the minimum standard certification, the ISO9000 series provides for a customer-supplier dialog to allow the customer to obtain customized quality activities for the products or services delivered. Among companies maintaining ISO9000 certification, there is still some variability in quality, but the quality levels of individual products are more predictable and uniform than for companies driven by market assurance alone. Part of the certification requirements include maintenance of basic quality records that can be made available to the potential customer base so that customers can accomplish an independent quality assessment prior to

buying a product or service. These records should be accessed by the system designer anticipating use of NDI as a fundamental part of the market survey.

The system designer must also analyze the system partitions to determine where exceptional levels of quality may be required and justified. At least the following system elements must be considered for special attention:

- Mission-critical elements (even if they are not designated as mission critical).
- Single point failure elements.
- Any element that has a high consequence of failure (safety critical, mission failure critical).
- High-value support items.

System elements that justify special quality attention will also require special attention for support, testing, and reliability assessment.

Good quality practices by potential suppliers should by complemented by good quality practices by the acquiring activity. Acquiring activity quality practices should include the following measures:

- Good system design processes and practices.
- Reliability program support.
- Test program support.
- Internal quality expertise to work with potential suppliers.
- Good market analyses and surveys.
- Cost-benefit analysis support.

System expertise must be assembled into an acquisition team and effectively employed throughout the development of system requirements, procurement, testing, fielding, and support.

Since many sources of NDI are driven by market quality assurance, it is often practical to add a post-production quality screen to provide some stability to the product being acquired. The practice of lot acceptance and periodic acceptance tests is normally redundant to supplier production quality practices and should be heavily tailored for the various COTS, ROTS, FCOTS, and NDS. Nevertheless, a limited periodic acceptance test can be useful to document the quality characteristics of dynamic products being used in a critical system application. A workmanship screen is often helpful for hardware items. For years, the Navy has successfully and cost effectively applied Environmental Stress Screening (ESS) (MIL–STD–2164) to COTS procurements as a matter of policy. Items failing the ESS can be reworked and retested. ESS can be applied by the supplier prior to final system assembly for large systems. For small systems (black box systems), ESS can be applied after delivery and failed items returned under warranty. In all cases, the system acquirer must judiciously tailor quality practices in order to achieve the system goals cost effectively. The most cost-effective means of achieving quality is through the process assurance obtained on high-rate production lines, but this is sensitive to market forces. The steps needed to tailor quality practices may differ for each NDI, and the information needed for effective quality management must often be obtained through the market analysis and tailored screen.

Quality issues are critical to solid system planning. Inappropriate decisions can make quality implementation into a program cost driver, especially in NDI acquisitions. In general, the highest

quality possible should be obtained from the suppliers without disturbing the supplier's best practices. If added quality is needed to overcome market inadequacies, it is usually best for one of the acquisition program's agents to take the necessary steps (tests, inspections, etc.) and to return defective items under warranty provisions. This approach obtains high quality without creating cost drivers in the commercial market. On the other hand, some markets offer high-quality options that greatly exceed DoD requirements; these options should be exercised with care to ensure that a reasonable price is being paid for the true needs.

CONFIGURATION MANAGEMENT (CM) ISSUES

Configuration Management (CM) is essential to any project. However, several CM issues are important to NDI projects. These include the following:

- Interface control.
- Level of control.
- Configuration identification.
- Configuration status accounting.
- Change control.

All of these issues involve modified perspectives and procedures when dealing with NDI versus development items.

Interface control is essential for NDI systems. NDI systems are usually characterized by frequent systems upgrades performed along form, fit, function system partitions. The top-level partitions must be thoroughly documented by the system designers so that the system function is not dependent on any second-order parameters (unspecified but essential for operation parameters). This may imply specialized characterization testing during the system design and prior to the writing of specifications for procurement. It is especially important to thoroughly characterize and document the hardware–software interfaces that may exist. Eventually, one of the major tools available to the life-cycle support agent of NDI (and especially COTS) is the interface documentation down to the level of support. This level of documentation establishes the level of standardization internal to the system architecture. Without effective interface control, modifications cannot be managed efficiently and life-cycle support is less effective. Interface control is also important because most of the NDI items are outside of the project's management control, so control of the interfaces provide the main method of technical control.

It is also important to establish a realistic level of CM control. If CM is imposed at a too detailed level of system complexity, the project will pay for huge amounts of unneeded documentation, and then continue to pay for maintaining that documentation. If CM is imposed at a too high level of system complexity, insufficient information will exist to maintain interface control, resulting in an inability to cost effectively manage changes, modifications, technical upgrades, and life-cycle support. System support decisions, level-of-repair decisions, technology infusion plans, and the exercise of CM control by the project office (through either the System Design Agent or the life-cycle support agent) all need to be coordinated and maintained consistently. The project office must maintain some level of CM control, but also realize that detailed control of the NDI product must remain with the product agent (the supplier in the case of COTS/ROTS; the original acquisition office in the case

of MILOTS and FME). A firm rule of thumb cannot be dictated for modifications and integrated NDI, but it is likely that the project office (through its agents) will desire to maintain CM control of the modifications. Occasionally, a system integration agent will be retained to maintain CM control of integrated NDI throughout its life.

Configuration identification is a fundamental CM function. The rule of thumb for NDI is to identify any NDI product as a configuration item. Since the configuration item level is generally the level at which most documentation requirements are specified, this rule will almost always result in a configuration item identification that is consistent with the interface control requirements and level of CM control desired. Whenever possible, only unmodified NDI should be a configuration item, and any modifications should be separately identified. This enables a stable system architecture that isolates the rest of the system from any major changes that may occur within the NDI over its product life. This makes life-cycle management much easier and more effective while not inhibiting the independent support of the NDI by the appropriate agent.

As an example of this configuration identification scheme, assume the desired system is a specialized application running on a Navy TAC workstation. The TAC workstation, POSIX operating system, X-Windows user interface, a commercial word processor, and Oracle database would all be NDI configuration items. Modifying scripts to interface through X-Windows, application macros for the word processor, and application script for Oracle would each constitute a configuration item, even though some of these items might be very small. Custom application software would be identified into configuration items in accordance with development rules of thumb (functional items not to exceed about 10,000 lines of source code). Such a system is very typical of integration NDI systems. This scheme of configuration identification has been found to be extremely effective in both cost and function.

Configuration status accounting is probably the most crucial CM function in most systems containing significant NDI functionality. It is particularly important to maintain good status accounting for COTS products. NDI product baselines may change frequently and irregularly. This can result in fielded systems built to the same product architecture still being different from each other in both detailed functionality and in support item requirements. Some COTS-based systems have hundreds of fielded configurations. A single installation site may have several different configurations representing the evolution of the system. Although the differences between systems may not be very significant, it is absolutely essential to maintain good status accounting down to the level at which the system is being supported. If this is not planned and executed, the fielded systems will invariably "break" because of some revision of an item, and the problems trying to troubleshoot the causes will be enormous. Good status accounting will not prevent "breakage," but it will allow quickly identifying the combination of items that do work versus those that do not work, resolving the causes rather quickly. Once the "A doesn't interface with B anymore" type problem is found, the solutions are usually well defined and quickly implemented. Also, NDI may be available from multiple sources with the same "form, fit, and function" but different internal parts.

An infrastructure for configuration status accounting can be established almost immediately as a system is partitioned by establishing and maintaining a work breakdown structure (WBS) down to the configuration items ultimately identified for the system. In a good system design, the WBS is stable even when elements internal to the configuration items change. A framework of references can be designed for every installation and planned future installation using this scheme. The references can be used to preload databases used for various support elements. The agent with configuration management responsibilities (the Life-Cycle Management Agent is recommended), can then

matrix all installed items (hardware, software, documentation, and training products) against these references. Interface data, performance metrics, specifications, and other information can also be matrixed to this reference system so that a consistent frame of reference is easily maintained for each installation that spans all of the system design and support issues. If the matrix is maintained in a suitable technical platform, all of the information can be accessed remotely or locally using web browser technology.

Change control is quite different for COTS applications. The COTS manufacturer will make changes for a variety of reasons without notifying customers. Normally, these changes will result in less expensive systems with better quality and reliability performance. However, occasionally the changes will result in poor performance in some environments. The system agent must then decide what to do. Ordering a product design change is usually not an option, and almost never a cost-effective option. Enabled by good status accounting, the system agent can determine the best course of action including:

- Stay with an older version of the NDI product (newer is not always better).

- Go back to the prior version of the product that worked, if available.

- Design new interfacing components to readapt the new NDI version into the system.

- Disqualify the NDI source and switch to another source maintaining the same standard interface.

- Rearchitecture the system to another, more stable, interface standard.

In COTS systems, all of these options may be viable; only two or three of the options may be workable in other forms of NDI. Acquisition managers and systems engineers need to recognize that usually over **10 percent** of a developed system will be changed annually for a variety of reasons. NDI systems often do not undergo any more annual change than this, except the change control is exercised by the product design agent rather than the system agent. The system agent is still maintaining change control, except that system CM change control is being exercised at a level above the NDI product level. Trying to impose lower levels of change control will result in added costs, and probably poorer, less responsive, overall control.

It is sometimes feasible to negotiate design revision locks on supplied items. This scheme does not allow the supplier to change the product without notifying the customer, and the customer has the option of not accepting a proposed change. If the supplier makes changes, the revision lock agreement ensures that spares will remain available to the old design. These agreements require that the customer pay a fee for the future access to old designs, are very hard to negotiate and maintain in the real world, and can result in not being able to take advantage of technology updates nor cost reductions in newer designs. Therefore, this approach should only be used for the support of products that are highly mature, where the market technology is not dynamic, and when the product interface to other portions of the system has a high number of second-order specification parameters (characteristics that are not fully defined nor controlled).

Technology infusion plans and other forms of pre-planned (system) product improvements need to be integrated into the CM plans. This will allow the needed interface characterization and testing to be planned and adequately funded to enable the system to be managed effectively throughout the transition.

SYSTEM LIFE-CYCLE PLANNING

System life-cycle planning provides long-term plans for the investments needed to keep addressing continuing operational requirements. The various types of investments range from modifying support plans to major technology infusions to a total rearchitecture of the system partitioning that amounts to a system replacement. The investment alternatives are normally considered to include these five:

- Modifying support.
- Product improvements.
- Technology infusions.
- System upgrades.
- System replacement.

Most system requirements address operational requirements that have existed for a considerable length of time and will continue to exist for the foreseeable future. For instance, there has been a need to effectively communicate between ships as long as there have been navies. However, the employment of naval battle groups has changed from the days of Roman triremes operating locally to modern navies having aircraft carriers and submarines deployed worldwide. National interests are now global and not merely the immediate coastline or fishing areas. As a result, the needs to communicate have certainly changed. Of course, technology has changed the nature of naval warfare even in the structures of ships and weapons; technology has also changed the nature of supporting systems such as communications systems. As a result, a system designer must plan for a relatively long system design life, even though the products composing the system may have relatively shorter life spans and even though there is an expectation for technological improvements that will be incorporated into the system.

There are nearly always major differences between component life, product life, and system life. The component life affects reliability and support planning because the component end-of-life results in a component failure and requires a maintenance action. The product life is determined by the economic support period. System life is determined by the viability of the technical approach in continuing to meet operational requirements. In any system, differences in component, product, and system life spans must be resolved. As the practical differences in product life and system life may be very subtle, there tends to be a focus on effective product life in determining when to initiate various support plans, technology infusions, system upgrades, and replacement systems; the result is either a failure to make timely investments to maintain system viability or to invest in product or technology upgrades that are untimely and ineffective.

At least eight factors are considered in designing the system life:

- Operational requirements stability.
- Operational requirements predictability.
- Ability of current technology to address the current/predicted operational requirements.
- Predicted technological growth.
- Technological cost trends.

- Potential technological sharing between markets.
- Existence and growth of technology standards.
- Production technology trends.

With rare exception, the operational requirements will continue well beyond the product life, so the system designer should try to design the system life to be as long as possible. The general trends of the operational requirements evolution will often be sufficiently predictable to allow the system designer to marry appropriate technologies into a technical approach that can remain viable for decades. Some well-designed systems have remained viable for over 50 years, although 30 years is more typical. Current technology is seldom able to meet the anticipated evolution of operational requirements; in fact, current technology may not even be able to meet all of the current operational requirements. Therefore, the system designer must select the best available technologies and create system partitions that will promote the cost-effective future exploitation of technology growth. At least half of the above factors are intertwined in the evolution and costs of the technologies that may be incorporated at some future time. All systems will be evolved over time; the degree of system life-cycle planning will determine how much the changes will cost as the system is evolved. These factors must be considered for all system acquisitions if the life-cycle costs are to be adequately controlled. Good system life-cycle planning will reduce the total amount of documentation needed, improve overall configuration management, maintain high levels of effectiveness in both operations and support, and provide high responsiveness to evolving operational requirements.

System support modifications only change the items supported without changing the system architecture. Even the form, fit, and function specifications for the product level do not change. A support modification may also change the procedures implemented for support or the place of performance of support actions in order to accommodate changes in the product character or other support circumstances. A new piece of the system might be included below the system support level that may require prescreening an item returned for repair to determine which depot maintenance activity should take the action. A new item may be "the same except for repair parts" as the item it replaces.

In product improvements, the system architecture remains intact and unchanged, but the product-level implementation is changed to add or modify functionality. This will result in the revision of the governing form, fit, and function specifications and add elements to interface specifications. Product improvements can be preplanned when a supporting technology is not sufficiently mature to address the required functionality when a system is fielded. Preplanning product improvements allows the changes to be inserted by engineering change proposal rather than having to recourse through all of the acquisition system procedures for acceptance and test. The procedures for implementing unpreplanned product improvements are still simpler than initial acceptance of a new system, but still require some rigorous tests and reviews of effectiveness and suitability. System support must always be modified in some way to accommodate the changes. An extreme example is to design a plane for a more powerful engine that is not immediately available but allowing the new engine to be installed as soon as it becomes available without modifying the rest of the plane.

Technology infusions are similar to product improvements and are treated administratively like product improvements in the acquisition system procedures. However, a technology infusion goes beyond the scope of a product improvement in that system design standards above the product level may be modified, and existing product-level system items may require modification to adapt to the new interface standards imposed by the new technology. The most cost-effective approach to technology infusion is to preplan the system design with appropriate interface points so that the new

technology can be integrated without modifying any system components. This might be the equivalent to changing a ship from steam propulsion to gas turbine propulsion; the change affects the engines but also requires changing the ship machinery spaces to accommodate the new engine characteristics.

A system upgrade involves rearchitecturing a major portion of the system and redocumenting the interface standards to accommodate the new technology. For example, changing out the system board in a personal computer to upgrade from XT technology to current technology would involve not only changing the system board but the hard drives, disk controller, expansion memory, video card (and video monitor as well in all probability), and most other major function cards because the current technology uses different bus structures and interface standards. Most of the advantages of the new technology cannot be exploited without changing the interface standards.

When none of the above alternatives are cost effective, the system is replaced, redesigning the system from the top down with new partitioning standards.

Systems employing a substantial COTS content must reconcile the relatively short product life of most commercial products with the desired long system life. COTS products are constantly changed to obtain better production efficiencies and to respond to market requirements that may have nothing to do with the system technical requirements; changes of this nature can require minor adjustments in the system support implementation. COTS products are also modified and evolved to incorporate new technology and to keep a competitive edge in technologically volatile markets; these changes tend to be very substantial, requiring action by the system Life-Cycle Management Agent (LCMA) (System Design Agent or In-Service Engineering Agent (ISEA), depending on the system phase). Most of these evolved products are changed so much that they are substantially new products with very little in common with the prior version. A typical product commercial life is **3 to 6 years**, compared to a good system life (after fielding) of **30 to 40 years**. The commercial product life in some high-technology areas is under 1 year. System designers strive to create an operationally flexible system architecture that can be easily adapted to new operational requirements, but substantial effort is still delegated to an ISEA to implement planned and unplanned changes. The primary tools for system LCMAs are product improvements and technology infusions.

Obviously, a product life changing in 5 to 6 years is not compatible with a system life that is six times as long. This implies that some major system restructuring actions will have to be done by the LCMA during the system life. By itself, this requires the system acquisition manager to plan to support the LCMA function for the life of the system and also to program funding to allow product improvement actions consistent with the expected product life spans. These can be major factors in computing the system life-cycle costs.

It is a recommended best practice for the LCMA to establish specification control drawings for each level of the product WBS **for each installation**. These drawings must be under the LCMA's control (rather than delegated to a system integration contractor). It is even a good idea to key the drawing number or extensions of the top-level drawing number to the associated work breakdown numbers (see the discussion of configuration status accounting under **CONFIGURATION MANAGEMENT (CM) ISSUES**). This allows support planning and provisioning actions to be done against these stable drawings while the LCMA performs a continuing market analysis of technology updates, technology infusions, and product versions. The LCMA can then perform configuration status accounting against the products actually fielded and matrix product improvements into the field by reference to the WBS-based control drawings. Similarly, technical manuals should be keyed

to each installation and to the product work breakdown. This is especially true for interactive electronic technical manuals. In this way, the LCMA can maintain consistency between the product data, support data, technical manuals, associated training, and other support elements in spite of frequent product updates and different installation configurations, while presenting a stable support environment to the user community.

Small acquisition projects will often partition their systems to utilize commonality with other systems that are already supported. When this is done, it is essential for the system commonality to be managed by a common LCMA. If this is not done, no economy of scale can be achieved, but even worse, the systems will get out of step with each other during the product improvements and technology upgrades that will take place over the life cycle. This usually results in the smaller system(s) becoming obsolescent and experiencing higher downtimes, higher costs, and lower availabilities. The common LCMA needs to ensure that all systems sharing resources share common upgrade paths and common interface specification documentation databases. The economies that can be achieved through common LCMA support can amount to 50 to 70 percent under the costs of supporting the systems independently.

SUPPORT PLANNING

Support planning for NDI acquisitions is similar in scope to planning for developmental acquisitions, except that the constraints are somewhat different. For the various off-the-shelf alternatives, support systems are already in place that may or may not be suitable for the intended application. Support planning for these systems needs to focus on what elements can be used directly versus elements that must be modified or developed. For the modification and integrated NDI forms, the support planning effort is normally a blend of adapting existing support and generating the support needed for the new or modified system elements. In either case, NDI acquisitions proceed much faster than the time it takes to establish final support; therefore, all NDI acquisitions become highly dependent on interim support, especially for training and spares.

NDI acquisitions are often plagued by inadequate funding for support elements. This is a result of two factors: a lack of adequate system planning and a perception that the planned support is out of scale to the overall acquisition. The first arises when the acquisition managers shift into a purchasing mode rather than acknowledging the need to develop the system requirements against which the procurements are to be made. The second occurs when acquisition managers fail to recognize that the support planning levels are relatively constant between NDI and developmental efforts, but the NDI procurement effort is significantly less than a development effort. This means that life-cycle support levels of effort may be significantly larger portions of both the initial acquisition budget and also the total life-cycle costs. For instance, typical developmental acquisition life-cycle costs break down to about 10 percent research and development, 30 percent production and installation, and 60 percent life-cycle support. A typical NDI acquisition life-cycle cost will break down to about 3 percent requirements development (the equivalent of R&D), 17 percent production and installation, and 80 percent life-cycle support. In a typical developmental acquisition, support planning normally constitutes about half of the overall R&D effort. In NDI acquisitions, support planning is about 75 percent of the requirements development effort. These differences in cost distribution often deceive those unfamiliar with NDI and can lead to managers underscoping the level of required effort in the support areas.

The usual tradeoffs are encountered in planning support between contractor support and organic support or some mix between contractor and organic support. The preference is toward contractor support, including warranty support because it is generally the most cost-effective support, sharing support resources across multiple products. However, organic support generally supplies the most responsive support with the lowest system downtimes. Also, organic support can function in combat environments where contractor support generally is not available. These tradeoffs are influenced by the usage and technology constraints. For instance, contractor support is more responsive to technology changes and can be made available almost immediately. Organic support is expensive to adjust for technology changes and can take years to establish or to alter to accommodate major changes. Organic support is especially critical when high operational availability is required for highly mobile or deployed systems. Contractor support is particularly effective for fixed site support, especially in non-combat environments. It is usually necessary to set up some hybrid support using some organic maintenance and other support capabilities, preferably managed by a central engineering capability such as the ISEA, backed up by contractor support.

INTERIM SUPPORT

All NDI acquisitions depend heavily on interim support. Interim support is provided by the acquiring agency rather than through existing support agencies. Costs for interim support must be budgeted by the acquisition program rather than being absorbed into support agency operating funds. Only the MILOTS, GOTS, and some FME acquisitions have sufficient existing support to avoid significant interim support problems; even in these cases, a system requiring significant increases in support levels will require some interim support while the existing support structure adjusts to the new demands. Many NDI acquisitions never leave the interim support mode; such systems are usually subject to such rapid upgrades that final support could never be established quickly enough to justify a transition from interim support. Other NDI acquisitions are low-population systems that are more effectively supported through interim support measures. Virtually all NDI acquisitions are so rapid that interim support is required; in fact, some acquisitions are so fast that it is a challenge to even establish interim support fast enough to field a supported system. In any case, interim support planning and timely execution are critical to the success of NDI acquisitions.

Interim support depends heavily on good engineering expertise to mediate support decisions; therefore, it is important to identify and establish the ISEA, Software Support Activity (SSA), and System Training Agent (STA) functions early. Interim support will normally use contractor support (warranty or field engineering) overseen by the engineering expertise representing the acquisition agency. Ideally, the ISEA, SSA, and STA should each participate in the generation of procurement documents and in the source selection process. This allows each activity to gain valuable information needed to establish and maintain interim support very efficiently, to identify the issues that will drive support, and to assign personnel with appropriate skills. Alternatively, the system design activity may be charged with the responsibility of planning and executing interim support if the system design activity has the appropriate expertise. In either case, it is desired that the interim support planners conduct a top-level logistic support analysis during the system design phase while partitioning decisions are being made. This allows the support considerations to be effectively integrated into the system partitioning decisions.

Virtually all systems incorporating NDI have architectures that require a close coordination between the ISEA, SSA, and STA functions (a fact justifying the establishment of a LCMA). These architectures have functional interfaces driven by existing "packaging" of functionality rather than by operator-observable functions. Problems are likely to cross system interface boundaries and to be

more difficult to accurately diagnose and resolve. The combined ISEA/SSA/STA expertise is often required to develop a true fix to the problem. For instance, a communication system having some NDI components was found to have a high number of software trouble reports that could not be duplicated in the test verification system; it was found that an error in the system technical manuals, which were also the basis of training, had an error resulting from a change in an NDI component that made it appear that there was a software problem. The SSA had insufficient information to recognize the source of the problem, and the ISEA and STA were not communicating with the SSA. The problem was finally recognized by an engineer from the original system design agency who happened to be aboard a ship during an exercise when the problem showed up. The engineer recognized the nature of the problem and notified all of the agents to correct the error. Problems of this nature can be common in systems architectures using NDI, especially if the system has a high number of technological upgrades being done over a short period of time or many different fielded configurations.

Interim support planning must provide for spare parts, hardware maintenance, software support, training, and technical documentation maintenance. Configuration management is essential for carrying these tasks out effectively. Each of these areas have their own unique problems that are discussed in separate sections of this document. In order to accomplish the tasks effectively, the System Design Agent (SDA) or LCMA should be tasked (and funded) to bring the ISEA, SSA, and STA functions on line as soon as possible to participate in the acquisition. Also, the SDA should be tasked to perform a top-level logistics support analysis integral to the system design and with the participation of the support agents. This will allow the issues arising from personnel, human factors, quality, reliability, configuration management, documentation, training, maintenance, and other ILS areas to be effectively considered and integrated into the system support plans. It will also allow funding for interim support to be identified early enough to be put into the budget in time for the support to be on line when the system is ready for fielding.

Special problems will occur when dealing with the rapid integration of NDI. Rapid integration projects can design and field a system capability within 6 months or less. In such programs, system design, NDI procurement, installation, generation of technical documentation, and support planning must proceed in parallel. The execution of all of these tasks must be well coordinated and flexible enough to accommodate changes that will inevitably occur. Weekly, if not daily, coordination between task leaders is mandatory. Most rapid integration projects experience difficulties because the product selection and integration must precede technical documentation, test planning, and training planning, leaving insufficient calendar time to accomplish these functions in traditional ways. The system integration tests, installations and checkouts, and initial training must all be very well coordinated since they will all be done within approximately the same brief calendar window. System documentation will often be delayed until after initial fielding, or it will be available in very preliminary forms. To meet these challenges, the following steps are strongly recommended:

- Identify and incorporate the different types of expertise, especially support system expertise, that is needed to acquire, field, and support the system and include the expertise as an integral and interactive part of the system acquisition team.

- Establish a strong developmental configuration baseline coordinated by the system designer or integrator.

- Ensure close coordination between all task leaders, with at least weekly meetings to discuss all issues from each perspective.

- Plan for the manpower/time for the system designers to develop the technical documentation needed at the system level.

- Coordinate system integration testing, installation and checkout activities, and system training. It is often possible for these activities to share facilities and personnel to the mutual benefit of all tasks.

- Design system training to also provide sufficient system overview information to allow for late delivery of system technical documentation. The resulting information must be in a form accessible to the trainees after the system is fielded and operational.

- Procure system spares with the initial buy.

- Plan for one or more complete systems to remain with the LCMA. This will allow verification testing for any future system changes and also provide a platform for emulating and diagnosing field problem reports.

- Provide for post-fielding on-site support for both maintenance and training for at least 6 months (calendar time) per site.

- Establish support coordination through the LCMA, including the establishment of ISEA, SSA, and STA functions. Make the SDA the single focal point for all required field support. This will allow support issues to be effectively identified and resolved while coordinating future installations and system design changes.

- Anticipate that changes will be dictated by issues that emerge after the initial fielding of the system. These changes should also include actions that will make the system more supportable.

Rapid integration projects require many decisions to be made "off-the-cuff" by the best expertise available. If good expertise has been brought to bear on each issue, good decisions will be made; however, some corrections should also be expected. A rapid integration program must plan and fund follow-on support. The scope of this follow-on support may equal or exceed the initial acquisition. The follow-on support must then transition to interim support.

WARRANTY SUPPORT

Warranties are expressions of the supplier's confidence that a product will meet or exceed the specified requirements for a stated period of time under specified usage conditions. The warranty is generally beneficial to both the supplier and the customer. The customer gets assurance that the needs satisfied by the product will be fulfilled or the condition will be remedied. The supplier can generally charge a little more (in the warranty contingency) than would otherwise be possible and still enjoy high customer satisfaction. If a product is particularly good, the warranty contingency becomes extra profit for the supplier. If the product is a "lemon," the customer still obtains the required service at no added charge, no matter how extensive that service might be. Therefore, suppliers have a market-driven incentive to build very good products covered by very good warranties.

Every product is supplied with a warranty, either expressed or implied. Virtually all commercial products are provided with a standard expressed warranty that is issued to limit the application of an implied warranty and to make warranty services a fixed cost for the product. The standard warranty is normally relatively short in term (30 days to 1 year) and is intended to cover latent defects and infant mortality failures. Extended warranties are often options that allow the customer to fix future costs over a major portion of the intended usage life of the product. Some markets offer lifetime

warranties, either because the product is of such quality/reliability that it is unlikely to require service within a user's life, because the product is associated with another product that has a definable limited life, or because the company is trying to protect a market niche from its competitors.

Most commercial warranties are of little benefit to military applications for one or more of the following reasons:

- The warranty term is too short. (The item may not even be put into service before the warranty expires.)

- The warranty is unenforceable because of field application conditions, environmental extremes, organizational maintenance requirements, or actions of field personnel violating warranty provisions.

- The warranty service provisions are not sufficiently responsive to maintain the required operational availability.

- The warranty is too limited in scope.

- The warranty requires actions that are impractical to implement (such as a quarterly inspection by an authorized representative).

- The warranty only applies to the acquiring activity and cannot be transferred to the user activity.

Most NDI acquisitions should use negotiated warranties tailored to the acquisition requirements. Negotiated warranties provide the benefits of commercial warranties while removing the limitations described above.

NDI acquisitions normally will negotiate warranties that are long term and with enforcement criteria tailored to the organizational use and maintenance environment. The following steps are necessary to establish a useful negotiated warranty clause that can be realistically bid by the potential supplier and mutually enforced:

1. The term should be established to be comparable to the minimum expected product life within the system. (This is normally about 5 years.) The term should be specified <u>in operating or usage hours</u> rather than calendar days, if at all possible. For instance, a system expected to be used 3000 hours per year could have a warranty term of 15,000 hours (the 5-year expected life times 3000 hours per year). To make this provision enforceable, a meter or other measuring device must be provided to keep a record of the usage; otherwise, some accepted measure (such as steaming hours or a multiplier of steaming hours, a value that can be retrieved from the Navy maintenance record databases) should be negotiated. If usage hours are not used, the calendar time of the warranty should start from the completion of installation and checkout. Also, special marking provisions are normally required for warranted items to prevent unauthorized or inadvertent maintenance actions that would violate the warranty.

2. The operator and maintenance skill requirements must be specified and consistent with the actual field personnel. The supplier must be responsible for ensuring that support/test equipment, manuals, training, human factors, test features, and all other factors affecting operator/ maintainer interaction with the product is adequate for the specified performance. If there are excess turn-ins due to poor documentation or training, the contractor should be responsible for bearing the costs and correcting the problems. The acquiring activity must ensure that all operator and maintenance personnel using or maintaining the product meet the specified skill/

experience levels and are available to the contractor or the contractor's agent for training. When the system is an integration of warranted items, the warranty provisions must recognize an adjudication of the reported problems by the acquiring activity agent (typically the ISEA).

3. The ISEA function must be established to manage the warranted items. The management function includes maintaining warranty records for each product, screening items returned for service for false removal, coordinating the shipping of items between the field and the contractor, and ensuring the warranty provisions are being met. (The ISEA does not necessarily accomplish all of these tasks, but merely directs their accomplishment. The supplier or a third party may be tasked to accomplish some of these tasks.) The warranty enforcement usually requires reporting at the field or organizational level, but this should be constructed so that no new or unusual reporting procedures are imposed. This requires the warranty manager to extract the warranty reports from existing maintenance record systems.

4. The supplier should be tasked to perform installation and checkout or to observe installation and checkout of each system to ensure that the warranted items are properly installed and functioning at the initiation of the warranty. If the warranted item is to be modified or integrated into a larger system entity, the supplier should be tasked to certify the modification or integration design as being suitable and within the scope of the intended use of the item.

5. Appropriate quality/warranty clauses should be included in the contract and tailored to the reasonable needs of the acquisition. The contractor should be liable for all costs for the products failure to perform to the specified requirements. This should include compensation for added costs if the product has excess failures (beyond those allowed by the specified reliability); however, these added costs must be identified and reasonable. Failures due to combat should be explicitly excluded. There are several clauses (under Quality Clauses, Section 52) available for tailoring in the Federal Acquisition Regulations that should be selected on the basis of the type of NDI being warranted. Specifically, the clause entitled "WARRANTY OF SYSTEMS AND EQUIPMENTS UNDER PERFORMANCE SPECIFICATIONS OR DESIGN CRITERIA" is particularly useful.

6. The contractor must be free to improve the product and to provide upgrades. The ISEA must assure that any upgrades/improvements still conform to system specifications.

7. The warranty should not be tied to a specific platform installation or configuration. (Some commercial warranties do not allow movement of equipment or software from one site to another.) The government should retain the right to establish pipeline spare pools to improve field availability or to change installation sites or configurations within established bounds. It may be necessary to change the mode of support from a two-tier to a three-tier mode in order to achieve the required system availability.

The negotiated warranty clause should normally be a separately priced option. It is important to expose the warranty cost, and the warranty cost should be reasonable. If contractor support services of similar scope are also bid as a separately priced option, the warranty cost should be slightly higher (by 5 to 10 percent) than the contractor support cost. This added cost is a measure of the risk being assumed by the contractor at fixed cost. A fixed warranty cost in this range should be considered equivalent in value to contractor support cost at the lower price since the contractor support cost will be adjusted in rate each year, and the demand for service will tend to rise near the end of the product life. In addition, the warranty provides an incentive for the contractor to improve the fielded product reliability since the unused warranty cost becomes added "profit" to the contractor. Use of the negotiated warranty clause is especially important for Integrated NDI.

CONTRACTOR FIELD MAINTENANCE AND OTHER CONTRACTOR SUPPORT

Virtually all COTS suppliers maintain some form of customer support. The level of support varies between suppliers and markets, but is generally stable for common products within a market. The range of field/customer support capabilities includes the following:

- Customer support line telephone service.
- Online BBS or Web Page support.
- Toll-free, 24-hour customer support line.
- Worldwide customer support line.
- Worldwide, toll-free, 24-hour customer support line.
- Factory service.
- Prorated product replacement.
- Total product replacement/exchange.
- Field office service.
- Worldwide field office service.
- On-site service (domestic).
- On-site service (worldwide).
- Combinations of the above.
- Contractor facility training.
- On-site training.
- Contract course training support.

The extensiveness of the service is influenced by the size of the company, the breadth of the product line (allowing products to share the common support), product support demands (failure rates and support complexity), and the market requirements. Each of these support capabilities provides a degree of responsiveness and a region of coverage, but at a cost. The range of capabilities might be an explicit customer option or included in the product price.

WARRANTY SERVICE VERSUS CONTRACTOR SUPPORT

The degree of field support is often a negotiable item for major NDI acquisitions. It is useful to request quotes for desired levels of contractor support as contract options. The quotes can be particularly useful when they are compared to similar quotes for warranty services. If there is a very significant difference between the contractor service quote and the warranty service quote, it indicates that the supplier is not confident of the product support demands (if the warranty is bid higher) or that the level of support requested is beyond the supplier's normal support capabilities (if the warranty is bid lower). For similar levels of support, the warranty should normally be bid at less than 10 percent over contractor service, with less than 5 percent more typical for mature products. The difference between the warranty service quote and the contractor service quote is called the "warranty premium" or the "supplier risk cost." Past experience, together with life-cycle cost analyses of future cost implications, shows that a warranty premium not exceeding four times the assumed average rate of inflation is equal in real value to contractor service agreements with annual rate adjustments.

SPARE PARTS

The level of sparing is impacted by availability requirements, reliability performance, and costs. It would be nice to never need spare parts, and if nothing ever breaks, spare parts are never demanded. However, even highly reliable systems require spare parts to cover those contingencies of unforeseen circumstances so that the system can be maintained and be available for use. Vital systems and mission-critical equipment have availability requirements that cannot tolerate long downtimes awaiting parts, so spares for such items must be positioned for ready accessibility if they are demanded. On the other hand, every replaceable item cannot be spared at the organizational level, even for the most vital or mission-critical equipment because of cost and space constraints for deployed units. (In the1970s, the Naval Material Command estimated that an aircraft carrier would need to be 120 percent larger in order to have sufficient storage space for all of the spare parts needed to support only designated vital and mission-critical items; the cost of the spares was estimated to be equal to the original cost of the ship. Similarly, a fleet ballistic missile submarine would have had to displace over 100,000 tons to maintain every possible spare on board throughout its deployment.) System planners must take these logistic constraints and support risks into account, while designing for maximum operational availability.

It is very desirable to keep the number of new items of supply to an absolute minimum. When fewer new items of supply are needed, there are more options for providing depth of support cost effectively and maintaining a very high operational availability. In development systems, standardization programs can be used to reduce the new logistics items that need to be supported with spares; however, this is usually not practical for NDI. There may be some flexibility in the system partitioning to maximize the standards within the system, thereby reducing the number of new items to be introduced, but this is made significantly more difficult by many of the new technologies and rapidly evolving technologies. In some cases, some redesign or modifications can reduce the spare part requirements. For instance, one system had 48 "computer-on-a-card" items in a common chassis consisting of nine different card types but enabling the use of off-the-shelf software. By modifying the software to operate on a single "computer-on-a-card" type, it became feasible to provide a spare card in the same chassis to guarantee spare availability. The minor software modifications allowed a significant improvement in system availability (from 0.45 to 0.987) while reducing overall life-cycle costs very dramatically simply by reducing the overall spare part requirements. A further reduction in life-cycle costs was achieved by selecting a card type of the original nine that was already provisioned for other systems. These two actions resulted in an overall reduction of spare part costs by 93 percent. To achieve these savings, good standards had to be selected for the system partitioning based on both industry market standards and the standards adopted by the military market (resulting in systems sharing the supply base).

Both reliability (failure rate) data and environmental performance data are essential to making informed sparing decisions. Much of the required information can be obtained during the market survey and screening processes. However, the confidence factors, as discussed under **RELIABILITY ISSUES**, must be taken into account. Information of low confidence levels will lead to over-sparing and unnecessary expense or undersparing with poor operational availability performance. <u>Each dollar spent in developing higher confidence information through screening tests can return in excess of one hundred dollars in reduced spare part costs</u>. Tests are considered complete when the confidence levels have been improved (when combined with all available information) so that the predicted insurance spares have been reduced to less than 10 percent of the total predicted spares (or to one spare). Technical Document 108 provides additional information on Support Parameters and

the practical constraints for different application environments that should be considered in the Conceptual Phase.

The difference between system life and product life must also be taken in account when making sparing decisions. If spares are provided for the system life, most of the spares will never be needed because the spared item will be replaced. The practical life of high-reliability products will probably not exceed the capacity of insurance spares that are provided merely to ensure availability. The spares for commercial items should be planned for the life of the product in the system. In most cases, the system life-cycle planning will indicate system upgrades amounting to about 10 percent of the total system functionality per year as a minimum before product life factors are taken into account. However, if the average life of a commercial product is 5 years and commercial support for the product is guaranteed for only 5 years beyond the product phase-out, system upgrades amounting to as high as 20 percent of system functionality per year might be required. Most commonly, the product will be incorporated into the system after it has been on the market 2 to 3 years, so the system is fielded with only 2 years of product life remaining (typical). The commercial spares availability can then be expected for only another 7 years. However, each product must be evaluated on a case-by-case basis for both product maturity and supplier support. Spares are only required for the period of time from the fielding of the system to the replacement of the product by a system upgrade. Ideally, each spare will run out at the same time that the last spared item is removed from the system. In practice, the insurance spares should be left over and need to be excessed, since they represent the number of spares needed to reduce availability risks to acceptable levels. The time span required for the insurance spares needs to span the remaining product life plus the commercial availability of spares time up to the <u>planned system upgrade period plus 2 years</u>. The 2-year added time results because funding for system upgrades cannot be assured, especially when the budget is being drawn down; therefore, an added budget cycle (2 years) is required to reduce budget risk to the planned system upgrade.

SPARING STRATEGIES

Spares may be provided at any or all of up to four echelons of maintenance support, depending on the support strategy and using agency policies and required operational availability. Organic spares provide the highest operational availability, but are limited by constraints of space and cost. Technical Document 108 provides additional information on Support Parameters to be considered in the Conceptual Phase and the constraints of various organizational levels of support capability. Spares maintained by an original equipment manufacturer (OEM) or supplier are least costly since they are only purchased on an as-needed basis; however, the lead times for the spare availability can be months under some circumstances—not acceptable for good operational availability. All sparing strategies try to balance achieving minimum costs and maximum availability within the system constraints.

Embedded spares and spares kits are good approaches for vital items with high operational availability requirements for COTS, ROTS, FCOTS, FME, most modified NDI, and Integrated NDI. These types of NDI tend to have high-value replacement items that are not military standard stock items. Nevertheless, the supply parts control centers or national stock system should be queried to determine if items being considered for sparing are already provisioned in another system. This information will also appear in a good item screen conducted during the system partitioning phase.

To minimize expensive organic spares, supplemental spares can be provided at an intermediate or depot level. The following alternatives for depot-level sparing should be considered:

- OEM support.
- Prime system integrator support.
- Contractor field service support.
- In-Service Engineering Agent (ISEA) controlled support with contractor back-up support.
- Supply system stocking.
- Life-of-Type procurement stocking (where the designated spares are maintained outside of the military supply system, usually under the direction or control of the ISEA).
- Escrow data rights (where data rights are purchased at a reduced cost and "held in escrow" for the contingency that if the supplier may goes out of business or ceases to support the item, a third party can use the data to produce the item).
- Purchased data rights (where the complete design disclosure is purchased from the original supplier for purposes of obtaining additional sources of supply in the future).

High-value items are normally controlled through the ISEA in order to avoid a high false removal rate. High false removal rates artificially inflate pipeline spare requirements and usually lead to con-tract disputes over warranty clauses. Also, major warranted items should be controlled through the ISEA. Lower value items and minor warranted items can use direct contractor support, although a common process for handling all items warranted by a single supplier is desired (even for different system applications). Life-of-Type procurement should only be used for unique items (such as application specific integrated circuits or heavily customized modules) that will not be maintained in manufacture or for support bridging between the end of contractor support and product phase-out. Data rights should only be purchased for vital and unique system elements where there is a signifi-cant risk of the loss of the original source of supply and where the technology is anticipated to be transferable to another source. The responsiveness of contractor support access through the supply system or through an ISEA can be improved by several techniques. One such technique is to estab-lish blanket ordering agreements with the supplier that allow telephone or facsimile orders to be placed. Another is called the Just-In-Time Paperless Ordering Procurement System (JIT–POPS); JIT–POPS places orders electronically (effectively an e-mail procurement), even allowing direct messaging from the user organization. Contractor field service support can be expedited through a special prearranged "credit card" agreement. Suppliers can (for a small fee) be required to maintain a guaranteed stock to support any of the rapid ordering methods. Any of the on-demand techniques have the advantage that expensive pipeline spares and other inventory spares are either reduced or eliminated.

MILOTS and GOTS items normally have an established sparing strategy already implemented. However, the existing strategy may not be appropriate for the particular application. For instance, a system previously provisioned for use on an aircraft carrier will require a different strategy if it is used by special forces teams. Wherever possible, an existing strategy should be used.

The methods employed to support NDI systems should not require modification of either the sup-plier's support infrastructure or the military supply procedures or maintenance reporting procedures. A well-designed sparing system blends the strengths of both support systems and ensures that timely and accurate information is obtained to make cost-effective repair/replace/upgrade decisions.

DYNAMIC SPARES

Many COTS products are changed so frequently that every time an order is placed, the part is slightly different. Many times the differences are of no concern because the form, fit, and function of the original item are maintained; however, changes outside of this realm can be of major concern to the user and support agents alike. Products in this category should normally be spared through the ISEA, and a special screening function should be implemented under the ISEA direction to ensure that incoming spares are compatible with existing fielded systems. This also requires the ISEA to maintain some level of certified pipeline spares. As the product evolves, it may be desirable to upgrade systems to eliminate incompatibilities with future spares, or to modify the architecture slightly to adopt a new or modified standard reflected in the new spares. On the other hand, changes may affect a hardware–software interface that may require changing software each time the spares are delivered. The system configuration must be maintained at current levels, documentation and training must be kept current and consistent with the new elements, and any changed specifications must be evaluated. These functions require an engineering oversight to the normal supply function. This has proven to be the most effective means of handling dynamic spares. It is essential that the market survey ascertain if dynamic spares are involved. Also, a notification clause should be used in procurement contracts to require supplier notification whenever a change is made in the production item.

Dynamic spares are also facilitated by strong configuration management employing an installation-specific product breakdown based specification control scheme as described as a *best practice* under the **CONFIGURATION MANAGEMENT (CM) ISSUES**.

HUMAN FACTORS

Humans participate as an integral part of a system to perform functions for which it is literally impossible to design a product solution. Humans are elegantly designed to deal with the real world and can also be viewed as the ultimate in NDI. Nobody can "design" or redesign a human for a particular system application, and the humans available to perform the system functions are highly variable in skills and abilities. The human factors design of the system and its component products together with training largely form the basis of human performance as part of a system.

Human factors can be very challenging to properly integrate into NDI systems. The system designer is faced with incorporating human factors in order to reach the system proficiency goals, safety criteria, and cost goals, but NDI products already incorporate human factors elements that are probably inconsistent with the standards already established for the system application environment. Since the military has been in the forefront of human factors technology in many specialty areas for many years, most of the application standards for human factors have been very well established, being entrenched in established rate training and years of use. On the other hand, most commercial practices have been established for different application environments where combat stress and fatigue are not driving factors. Furthermore, commercial practices are just that—practices; they are not industry standards that are well coordinated across the entire market. This can result in several pieces of NDI being assembled into a system that have different user interface standards. The individual pieces may have adequate user interfaces, but the inconsistency across the system cannot be tolerated. Also, NDI may be available from several sources, each with their own unique user interface (for instance, the different advanced controls between VCRs or microwave ovens); this situation

can lead to intolerable differences from system to system. To cope with these issues, the following steps are recommended:

1. Identify and document the human factors standards that are associated with the intended applications.

2. Identify and document the other human factors issues that are critical to system proficiency, reliability, and safety (including conditions of combat stress and fatigue, of potential operator error, and of organizational maintenance).

3. Prioritize the issues and design factors from steps 1 and 2 above as essential, important, and desired, and incorporate into the tailored screening criteria.

4. Review potential candidates for conformance to essential standards and for incorporation of important and desired features. Also, determine if design standards incorporated in the NDI are in conflict with essential or important criteria. Use the human factors criteria as part of the overall ranking of candidates.

5. Determine if there are means for bringing each candidate into conformance to essential standards.

6. Determine if there are means for incorporating important or desired features cost effectively.

7. Incorporate human factors criteria in the source selection criteria. Design and implement modifications for selected candidates to maximize human factors compatibility, as required.

The first three steps are crucial to high-quality system designs and their cost-effective implementations. Too often, human factors criteria are disregarded because the NDI already has established designs that are difficult or impossible to change. However, the good system designer can usually work around these limitations and still maintain the cost advantages of the NDI acquisition. The techniques available for NDI not conforming to essential criteria are listed below from most preferred to least preferred:

- Remoting or encapsulation.
- User shells.
- Repackaging.
- Redesign.

Remoting uses the NDI in its native form (unmodified) but implements remote interface features to a user interface that does conform to the required/desired standards. User shells provide a conforming interface as an intermediate interface between the user and the NDI. User shells are often possible for software applications where the shell translates between the desired user interface and the user interface designed into the application. Many commercial applications include macro-language features to promote application customization through user shells. Often the core/required functionality of the NDI can be easily repackaged to conform to established standards. For instance, the knobs of a commercial radar can be changed to conform to the functional shape standards of MIL–STD–1472. In the extreme, the functional elements of the NDI might be physically repackaged in a new housing having conforming user interface standards. Many software applications written for UNIX/POSIX operating systems have the capability of replacing the user interface with a customer-designed interface; this is equivalent to repackaging. Redesign is the most radical step where the user interface and underlying design features are modified to bring the NDI into conformance.

Human factors requirements are extremely important. Good human factors is essential for good system operation under all conditions. Good human factors can also dramatically lower training and maintenance costs by improving the organizational capability to interact properly with the system. The human factors requirements can have so great a system quality impact that they are the primary reason for modifying NDI.

TRAINING

Training should be considered integral to and an essential part of any system. NDI acquisitions are prone to miss important training issues because there is a strong tendency to focus on the product acquisition alone. Also, NDI acquisitions are often executed so rapidly that any training that needs to be developed often cannot go through normal or recommended training development cycles. When training must be developed for a product that can be fielded in under 6 months, there are severe strains put on the "smart buyer" team executing the system acquisition. When training already exists for NDI, numerous tasks must still be done to integrate the training into the entire system acquisition.

TRAINING SITUATION ANALYSIS

The Training Situation Analysis is fundamental to the determination of training needs for a new system. In developmental acquisitions, the analysis is conducted after the system design but prior to the Engineering and Manufacturing Development Phase so the training can be developed while the products are in detailed design. In NDI acquisitions, the analysis must be conducted concurrently and integrated with the system design since the analysis partially depends on system partitioning decisions. However, there will still be training analysis effort required after the system design is complete. The purpose of the training situation analysis is to determine what skills are needed for the system and for system component operation and maintenance, what existing training supports these requirements, what existing training (ranging from formal classroom training to on-the-job training) may be impacted by the new system, what new training is required, what NDI training may exist to support the new system, what training costs exist, and what training resources need to be acquired or developed to support the system.

For integrated NDI and major modifications, enough time is usually available for the training analysis and any training development to be done while the modifications and integration are being designed and executed. This allows the training to be validated and introduced through relatively normal procedures. However, any training requiring development must usually be designed and delivered on an accelerated schedule.

Other NDI being acquired as system or major subsystem will normally have NDI training as well. During the market analysis, a training screen should be incorporated in the assessment of potential candidates. The tailored screening process can include the validation of NDI training as a part of the product demonstration. Alternatively, the NDI training can be validated during the source selection process or as a part of the first article acceptance; however, earlier is better as it allows for modifications that might be required. If the existing training is adequate, it should be acquired integrally to the NDI system acquisition, incorporating any modifications determined to be necessary.

Other NDI being acquired as products assembled into a system should also have a training screen incorporated into the assessment of potential candidates. However, system-level training will need to

be developed in addition to any product-level training that might be acquired with the NDI. If resources are limited, sufficient training analysis needs to be done to allow the design and conduct of this system-level training concurrent with the fielding of the system, even if other analysis tasks need to be deferred. The system-level training needs to cover those issues above the product (black box) level, plus any operation and maintenance elements at the product level that have system-level implications. These types of acquisitions seldom have enough schedule available for validation of training or documentation, so the post-fielding assessment activities become very important to the meeting of overall system quality goals. Supplemental training after fielding must be planned and funded as well, since the system-level training will not touch all of the issues needed for adequate system use and field maintenance. It may also be necessary to retrain the initial field users and maintainers after the final training packages are ready.

All NDI acquisitions should include a post-fielding training assessment to allow emergent issues to be discovered and incorporated into the full system training package.

SYSTEM-LEVEL TRAINING

There is a large tendency to focus on product-level training in NDI acquisitions to the detriment of system-level training. This is especially true of NDI modifications to existing systems and for NDI system upgrades. The result is for training to be included for each individual piece of the system but for many system-level issues to be omitted. The most difficult of issues to discover are those that arise from new modes and capabilities introduced by a "black box" (or new software application). The training might be available for the operation and maintenance of the "box," but the implications of the new capability at the system level will not be understood.

Software trouble reports have been made against fielded NDI systems where no software existed simply because system training and system documentation were inadequate. The field personnel would not be able to bring up the system because equipment were in different modes (unknown to the operators/maintainers), yet check out each box only to find it was properly functioning. The presumption was that there must be some piece of software causing the problem. In fact, it was a failure of the system life-cycle maintenance function to identify, document, and provide training to a new system mode that was not covered by system-level training or system documentation.

TRAINING ASSESSMENT SCREEN

A training assessment screen should be done as an integral part of the market survey. The training screen should not be used to eliminate potential candidates; however, it should be used to:

- identify existing training associated with each candidate,
- evaluate the methods of training delivery employed,
- document training issues at the NDI product level,
- develop information on NDI training costs, and
- determine what training resources may be required, peculiar to the NDI.

The training screen thus includes many of the elements of the training situation analysis tailored to each NDI candidate. The information developed by a training screen is critical to the development of suitable training within the compressed schedules commonly encountered in NDI acquisitions.

INITIAL TRAINING

Initial training for NDI systems should be planned prior to and integrated with each system installation. It is common for each NDI installation to be slightly different, so it is important to document and train to these differences. If the system is to be supported by formal classroom training, it is very common for this training to not be available until the NDI system has been in the field for several years, so it is critical that initial training be planned to cover, even overlap, this formal classroom training. In addition, the system upgrades and overhauls that will occur during the system life will require initial training even if formal classroom training is on line.

Generally, formal classroom training will not be the primary mode of training delivery for most NDI systems. Classroom training may be the best mode for delivering the overview information and system-level training, but much of the product-level operation and maintenance training may be so "box" specific that only embedded or on-site/on-the-job training will be sufficient. A system planner should expect that the effort to develop quality training for an NDI system will be an appreciable portion of the overall system support effort.

TRAINING DOCUMENTATION

All training information, whether procured or developed, should be translated into an electronic medium (preferably a CALS-compatible format). NDI systems tend to be highly volatile because the product lives are relatively short compared to the system life, making system upgrades necessary. Also, there may be a multitude of different system configurations. As a result, the training packages might need to be tailored to each configuration and become site dependent. In any case, training documentation needs to be integrated with the installed configurations and maintained under common configuration control. The electronic maintenance of training allows the training to be updated effectively and efficiently on a site-by-site basis, as required.

Post-Fielding Training Assessment

A post-fielding training assessment is a good idea for any complex system. However, NDI systems can be complex while appearing to be simple; therefore, a post-fielding assessment should be done in any case to ensure system quality and to control risks. Ideally, a post-fielding assessment should take at least the following "snapshots" of the system:

- Within 30 days of installation or during exercises or refresher training.
- After 4 months of use or immediately prior to deployment.
- After 1 year of use or immediately after deployment.

It is especially critical to capture information immediately after a system deployment for Navy ship installations because there is often a crew rotation shortly after the return from deployment, and the information will be lost if the assessment does not capture it prior to their leaving. (An assessment team might even be sent to ride a ship back from deployment in order to ensure that the information is captured.) The goals of the assessment include the following:

- Assess the adequacy of existing training.
- Determine if there are any additional issues that should be covered by training.
- Determine the accuracy of training provided, especially compared to actual system use.

- Assess the integration of training with the overall system and with other system support elements.

Following these assessments, the project should determine if additions, corrections, or other modifications are needed to existing training. The project should also be prepared to conduct supplemental training if added issues are discovered or if major modifications to the training package are indicated.

DOCUMENTATION

Most of the issues relating to documentation are discussed in the DATA ACQUISITION section; however, two special issues are discussed here—readability and completeness. Several forms of documentation normally create subtle problems in NDI acquisitions, especially COTS acquisitions: operator and maintenance technical manuals, software interface control documents (such as Interface Design Documents or the interface section of a System Design Document), and installation and specification control drawings.

Technical manuals associated with COTS are written for the market requirements. COTS maintenance manuals are commonly written for a reading grade level far above the service standard for the designated operator and maintenance personnel. (Most large city newspapers use a fifth-grade reading level, which is below virtually all service standards.) COTS manuals often contain company-unique, product-unique, or market-unique jargon. (For instance, a speech processor used in the music industry may have terms unique to musicians familiar with the technology. When used for a military communication system, the operators and maintainers are unlikely to know the special terminology used in the technical documentation.) This implies rewriting the technical manual. On the other hand, some MILOTS operator manuals written for other service requirements are written very far below the standards for the target personnel, resulting in a manual that does not communicate well. These manuals may also require modification. Manuals for foreign items may require translation, and the translation may need to be rewritten to make it more readable. In all cases, it is important for the manuals to be written concisely and clearly for the target population, taking into account that the target population may have less training and fewer skills than what was desired by the system designers. Obtaining the manuals in an electronic form (even unformatted text plus pictures), promotes the cost-effective translation of the information into a suitable form for delivery to the users and maintainers. This allows some of the powerful computer-based tools to be applied to aid in tailoring the readability as well as creating interactive electronic technical manuals and embedded online documentation.

Software interface documentation is notoriously difficult to "get right." Very often, NDS interface documentation is limited to a small paragraph on the side of the shipping box. Even GOTS software is usually deficient in specifying the interface requirements. The primary difficulty is identification of the possible interfaces in an open architecture environment. A specific software application may need certain resources to load and run effectively, and the accumulation of applications running concurrently may still be well within the advertised capacity of the computer resources. But one application may still demand specific resources at the same time as another and cause the system to crash, hang, create errors, or respond in other unreliable ways. It is almost always a requirement to include stress tests of hardware–software combinations as a part of the screening process in order to determine what unreliable behaviors there may be and what the conditions are that cause these behaviors. When such behaviors are discovered, the existing interface documentation must be

modified or supplemented to avoid the problems. Additional system management software may be needed to mediate the potential problems that cannot be operationally tolerated.

Once the issue of completeness is resolved, software interface documentation must also be checked for readability. In this case, readability and clarity of the requirements documented are both essential. It is a good practice to perform a formal inspection on all software interface documentation prior to its acceptance. In fact, a formal inspection may be performed prior to resolving the completeness and accuracy issues noted above, and a second inspection performed afterward. Since the documentation for software interfaces is increasingly being produced in computer-aided software engineering environments, it is available in electronic form. However, there are no current industry-recognized standards for the database form of this kind of documentation, so the preferred electronic format supplied may not be compatible with the tools available to the system software support activity tools. To ensure tool readability as well as human readability, it is usually necessary to conduct some data transfer experiments until the right combination of file formats is found to make the data readable without losing any information. Drawing documentation has a similar problem, as noted below.

Control drawings are also problematical for most NDI. Interface and specification control drawing tend to be incomplete and may make references to company standard processes or procedures or specifications that are not part of the disclosure package. It is important to review critical documents for completeness and to ensure that all information needed to interpret the drawings is made available. In addition, the documentation can be validated through use by a third party (such as an installation activity or In-service Engineering Agent). Formal inspections are useful to ensure completeness, and should be conducted prior to acceptance of the documentation.

When drawings are provided in an electronic medium, it is important to run tests of the readability. Many of the applications used to create the drawings use proprietary file formats that are translated in order to be delivered in a preferred electronic format. Data can be lost or changed through the translation process, even by translators written by the supplier of the application. By performing test exchanges, any problems can be discovered early and workarounds or fixes can be identified. Also, while it is desirable to obtain all data in CALS-compatible file formats, it is often necessary to receive the data in a commercial standard and to convert it to a CALS format.

SYSTEM DOCUMENTATION

System-level documentation often does not exist for new or modified systems employing NDI. Instead, there will be an assembly of the documentation for all of the products that make up the system. System documentation may exist only for installation and checkout purposes, but be missing for mission application and maintenance. These circumstances arise because the system is designed out of NDI pieces, and documentation already exists for each piece of NDI. However, the existing documentation may not be appropriate for the system purposes or may omit critical system usage information such as concepts of operation, concepts of support, and system-level maintenance. Numerous systems have been fielded with this deficiency, causing excessive trouble reports and expensive but avoidable maintenance actions. For NDI, it is especially critical that each system upgrade also be covered by revised system documentation, since the upgrade probably introduces new modes and capabilities that are previously undocumented. Even if a capability of a piece of NDI is not being used, its existence and the fact that it is not used should be documented in the system documentation. This circumstance can result in a need for the system documentation to be site dependent. If this is the case, the system documentation must be carefully controlled as a

site-dependent configuration item. The cost-effective and efficient maintenance of system documentation is greatly enhanced by maintaining it in an electronic format. The system documentation must also be thoroughly reviewed for accuracy each time a change is made to any configuration item in the system, as there may be new issues introduced to the system level from lower level product changes.

System documentation and supporting product documentation should be reviewed for accuracy and utility as part of a post-fielding assessment for all NDI systems. (See **Post-Fielding Training Assessment**.) Attention to the generation and maintenance of quality system-level documentation promotes higher system quality in the field and makes system-level training much easier to teach and maintain.

SOFTWARE ISSUES

Several different classes of software are encountered in NDI systems. Clearly, there is Non-Developmental Software (NDS) and its major subset, Commercial Off-The-Shelf Software (COTSS). Modification software is that software needed to adapt COTSS or other NDS into a new application. Modification software is distinct from NDS that requires modification for application to a system; NDS requiring modification is simply modified software (although the modification is restricted to be less than a 30-percent change as measured in source lines of code or some similar metric). Integration software is the software "glue" used to functionally link items within a system; most integration software is newly developed for the specific application. Other newly developed software, modification software, and integration software can be managed as a single set.

In addition to the traditional types of software—applications, databases, and operating systems—it is necessary to define several subsets of application software as distinct types. Hidden software is code buried within an off-the-shelf configuration item that is not visible at the configuration item interface. Interface software directly implements interfaces to existing external standards. Interactive software only partially implements the functionality of a particular configuration item and is visible at the interfaces to the configuration item. Application software then assumes a more limited definition—that software fully implementing a system function and constituting a self-contained configuration item (i.e., a computer software configuration item [CSCI]). Each of the software types can be represented by any of the above classes. This creates a matrix of requirements for the acquisition and life-cycle management of software as given in table 4.

Table 4. Software acquisition and maintenance strategies.

	NDS, incl. COTSS	**Modified Software**	**Integration Software**
Hidden Software	Acquisition—Obtain existing documentation as provided with existing product package Maintenance—All source support (license agreements, warranties, contractor service agreements). ISEA or LCMA monitors configuration status.	Acquisition—Obtain existing documentation as provided with existing product package Maintenance—All source support (license agreements, warranties, contractor service agreements). ISEA or LCMA monitors configuration status.	Acquisition—Obtain existing documentation as provided with existing product package Maintenance—All source support (license agreements, warranties, contractor service agreements). ISEA or LCMA monitors configuration status.
Interactive Software	Acquisition—Obtain existing documentation and product Maintenance—All source support (license agreements, warranties, contractor service agreements). ISEA or LCMA monitors configuration status.	Acquisition—Obtain existing documentation and product Maintenance—All source support (license agreements, warranties, contractor service agreements). ISEA or LCMA monitors configuration status.	Acquisition—Obtain existing documentation and product. Acquiring activity performs limited quality reviews Maintenance—All source support (license agreements, warranties, contractor service agreements). LCMA CM.
Application Software	Acquisition—Obtain existing documentation and product Maintenance—All source support (license agreements, warranties, contractor service agreements)	Acquisition—Obtain Maintenance Plan, requirements and design documents, VDD, and code. Acquirer performs limited quality reviews Maintenance—SSA organic support and LCMA CM	Acquisition—Obtain Maintenance Plan, requirements and design documents, VDD, and code. Acquirer performs full quality reviews and audits. Maintenance—SSA organic support and LCMA CM
Databases (DB)	Acquisition—Obtain existing documentation and product Maintenance—All source support (license agreements, warranties, contractor service agreements)	Acquisition—Obtain Maintenance Plan, requirements and design documents, VDD, and code. Acquirer performs limited quality reviews Maintenance—SSA organic support and LCMA CM	Acquisition—Obtain Maintenance Plan, requirements and design documents, VDD, and code. Acquirer performs full quality reviews and audits. Maintenance—SSA organic support and LCMA CM
Operating Systems (OS)	Acquisition—Obtain existing documentation and product. Maintenance—All source support (license agreements, warranties, contractor service agreements)	Acquisition—Obtain Maintenance Plan, requirements and design documents, VDD, and code. Acquirer performs limited quality reviews Maintenance—SSA organic support and LCMA CM	Acquisition—Obtain Maintenance Plan, requirements and design documents, VDD, and code. Acquirer performs full quality reviews and audits. Maintenance—SSA organic support and LCMA CM
Interface Software	Acquisition—Obtain existing documentation and product. Acquiring activity performs limited quality reviews Maintenance—Source or contractor support with LCMA CM	Acquisition—Obtain Maintenance Plan, requirements and design documents, VDD, and code. Acquirer performs limited quality reviews Maintenance—SSA organic support and LCMA CM	Acquisition—Obtain Maintenance Plan, requirements and design documents, VDD, and code. Acquirer performs full quality reviews and audits. Maintenance—SSA organic support and LCMA CM

The primary issues for acquisition are (1) the types of documentation to be acquired with the product and (2) the extent, if any, of quality reviews or IV&V to be done. For maintenance, the issues are (1) who is responsible for maintenance and (2) who performs configuration management. Since hidden and interactive software is intimately tied to the hardware product, these forms of software are best handled together with the hardware as a single configuration item. Interactive integration software usually requires some degree of quality oversight because of its complex interactions with other system components. NDS, including COTSS, products should be handled as "shrink-wrapped" products complete with support; special service agreements, perhaps with a licensed third party, can be negotiated when the normally available support is not adequate. Many systems will contain a mix of these software classes and types, so procurement documents must provide for the flexibility in dealing with the full range of variability in terms of configuration management and quality management activities and tasks plus the acquisition of the needed level of information. Even though modification software and integration software require essentially the same documentation, the extensiveness of the documentation for modification software may be limited to only those elements associated with the actual modification plus the interfacing elements.

ROLES IN NDI LIFE-CYCLE ACQUISITION AND MANAGEMENT

Buying NDI raises issues that dictate some new definitions to the traditional roles in the life-cycle management of systems. There are significant differences in the requirements for planning for the system life cycle of COTS-based systems from developmental systems that have implications in the types of expertise required for the operations and support phase management, in the funding needed to support technology upgrades, and in the facilities needed to maintain configuration control. Furthermore, the rapid changes in system configurations characteristic of NDI systems dictate closer relationships and coordination between the major players in the life-cycle support of the systems. Continuing organizational relationships require long-term agreements and funding commitments that can be difficult to establish contractually or to fund in eras of shrinking budgets. This section discusses these issues and makes recommendations based on the NDI program relationships that have been most successful.

The roles of the various managers and agents are defined in various Systems Command instructions. These instructions vary in the titles assigned to the various roles but are in practical harmony with regard to the issues discussed herein.

ACQUISITION/SYSTEM MANAGER

The Acquisition or System Manager ("Manager") is the designated representative of the Systems Command or Program Office responsible for planning and executing the acquisition from the documentation of the requirements through its introduction into operational use. This includes the overall program management and technical direction of engineering, including capability, assurance requirements and assessment, maintenance engineering, configuration management, and logistics support. The Manager has the responsibility of planning and implementing the system life-cycle support, including pre-planned product improvements (P^3I), consistent with applicable laws, regulations, and policies. While the overall responsibility lies with the Manager, engineering agents are available to do the detailed work to achieve the program goals established by the Manager. The following NDI issues are important to the Acquisition/System Manager:

- Funding—for the entire acquisition phase and into the operations and support phase. Program decisions should be life-cycle cost-based. For NDI systems, the funding of life-cycle management activities and technological upgrades are critical. An entire product change-out may occur in 5 years or less.

- Acquisition support activities—the acquisition team must provide "smart buyer" capabilities and conduct the market surveys needed to make accurate decisions. This normally involves forming an integrated team with representatives of R&D, ISEA, SSA, training, and life-cycle management activities. The support activities must also be in a position to address the issues that have been identified in this document.

- Acquisition Planning—acquisition plans must be constructed to maintain an optimum competitive environment. NDI systems risk forcing sole source support of high-level equipments or subsystems (in contrast to components or minor assemblies) of considerable value unless a life-cycle management support infrastructure is established.

- Procurement Planning—source selection plans should take advantage of the information available and the capabilities that can be demonstrated with NDI systems while also accounting for the potential gaps and low confidence levels associated with some of the information needed for support planning of NDI.

- Support planning—support plans need to provide for the flexibility to use contractor support services and/or warranty services while maintaining high levels of operational availability and to account for the issues of many rapidly changing configurations.

ASSURANCE ENGINEERING MANAGER (AEM)

The Assurance Engineering Manager (AEM) or Logistics Manager is the designated representative of the Systems Command or Program Office assigned to support the Manager in system assurance issues and is responsible to the Manager for the interpretation and effective implementation of DoD and Systems Command policies for reliability, maintainability, availability, supportability, sustainability, safety, and quality. AEM responsibilities extend throughout the life of the system. Primarily, the AEM is responsible for coordinating system assurance issues among the engineering agents, ensuring that system assurance issues are properly represented in system documentation and procurement requirements, providing for the conduct of appropriate testing to verify that system assurance requirements have been met, developing affordable and effective support plans, and ensuring that systems assurance issues are addressed appropriately at milestone decision reviews and other significant acquisition reviews. The following NDI issues are important to the Assurance Engineering Manager:

- Determining and implementing support requirements in order to achieve the required operational availability. Many support constraints imposed by the commercial support of COTS are not consistent with high levels of operational availability unless special support features are built into the system.

- Implementing effective support plans that address the issues raised in this document, especially the rapidly changing internal configurations of many NDI products that are uncontrollable by the program.

- Making affordable and effective support decisions based on lower confidence-level information.

TECHNICAL DIRECTION AGENT (TDA)

As defined by Systems Command instructions, a Technical Direction Agent (TDA) is a DoD agent with the charter to serve as the director of systems engineering activities and responsible for implementing the tasks defined by DoD Instruction 5000.2. TDA responsibilities may be retained by the cognizant Systems Command or assigned to a field activity, such as a Navy Laboratory/Warfare Center. In either case, the TDA assists the Manager in establishing system concepts, defining a technical approach, defining system requirements (including procurement requirements), performing/directing research, development, tests, and simulations to investigate technical issues, probing alternative technical approaches, and evaluating design agent achievements. The TDA must oversee the conduct of the market research functions and define/approve the acceptable standards criteria to be used in the system partitioning. The TDA must also coordinate the SDA, DA, SIA, AEA/ISEA, SSA, STA, and LCMA activities and taskings through the acquisition phase. The following NDI issues are important to the TDA:

- Analyzing market research/implications of the findings.
- Defining procurement requirements that are performance based and that cite appropriate interface standards.
- Defining screening requirements.
- Assessing information needs and confidence levels.

SYSTEM DESIGN AGENT (SDA)

The System Design Agent (SDA) is responsible for transforming operational requirements into a preferred technical approach and for performing system partitioning functions down to the level that performance specifications can be prepared for tasking a design agent or making a procurement. The SDA may be a DoD agent or a contractor. When the SDA is a DoD agent, the SDA is often an extension of the TDA function. If the TDA is retained by the Systems Command, the SDA is often a field activity tasked by the TDA. It is also possible for the top-level SDA functions (interpretation of operational requirements and top-level system partitions) to be performed "in-house" by a DoD agent and the remaining, lower levels of the system partitioning, to be performed by a contractor. If the SDA is a contractor, the contract should be administered/technically controlled by the TDA. The following NDI issues are important to the SDA:

- Managing system requirements in the acquisition phase, including P^3I. This is especially critical for requirements stemming from the system being a part of a larger set of systems forming an operational capability.
- System partitioning consistent with potential NDI.
- System partitioning consistent with market research results.
- System partitioning consistent with preferred/acceptable interface standards.
- Documenting interface standards, including the variable flavors encountered in commercial standards. Also, the potential problems in documenting market-driven commercial standards or company proprietary standards.
- Selecting interface standards consistent with the likely evolution technologies.
- Including system assurance issues in the overall system architecture.

The interactions between these issues often cause communications problems between the SDA function and the other systems engineering functions being directed/coordinated by the AEM and TDA. Also, the choice between a DoD agent or contractor functioning as SDA should not be made on the basis of "we've always done it this way." Systems that have critical or vital operational requirements should have an in-house SDA function. Likewise, one-of-a-kind systems should have an in-house SDA. Medium to large quantity acquisitions having a high degree of rapidly changing technology that depends on commercial standards are normally best served by a qualified contractor SDA, although retention of the SDA function by the TDA is always appropriate (qualified consultative contractor support can be used to supplement in-house expertise).

DESIGN/DEVELOPMENT AGENT (DA)

The Design/Development Agent (DA) translates performance requirements (including those for product improvements) into a product design. Except for rare cases in development acquisitions of few-of-a-kind unique requirement systems, the DA is a contractor. For COTS, ROTS, etc., the DA is the commercial producer of the product, although a vendor independent of the producer may be the actual source of supply. In NDI systems, the DA is totally independent of the Manager; however, the DA is the ultimate source of both the product and the design information that is needed for operation, maintenance, and training support. The following NDI issues are important as related to the DA:

- Obtaining interface design information—this can be especially difficult when market-driven standards or company proprietary standards are involved.

- Obtaining system assurance information of sufficiently high confidence—this type of information may not be available or may be available in a form that is difficult to interpret; there may be insufficient data to achieve high confidences, especially for NewCOTS.

- Translating DA sourced information into a form usable with the system or incorporating supplier information into final system information—the commercial forms and company-specific formats are often not acceptable and may not be available in an electronic form that makes the information easy to manipulate.

- Configuration management information—CM is not conducted within the product but at the product interfaces; nevertheless, the DA seldom has any contractual responsibility to provide even notifications of changes.

Since the DA is not available to perform these functions in an NDI acquisition, the functions must be picked up by other agents or activities. Initially, these functions may be assumed by the System Integrator; however, all of the functions may be accomplished by the AEA/ISEA functions.

ACQUISITION ENGINEERING AGENT (AEA)

The AEA performs all of the functions of the ISEA in support to the Manager during the acquisition phase. Usually, the AEA, a DoD agent, is also the same activity that is planned to be the ISEA; this promotes the smooth transition of system support from the acquisition phase to the operation and support phase. The following NDI issues are important to the AEA:

- Covering the gaps created by the inaccessibility of the DA—see **DESIGN/DEVELOPMENT AGENT (DA)** section above.

- Conducting or overseeing workmanship/quality screens (such as Electronic Stress Screening [ESS]) added as an incoming inspection screen or to a production line.

- Preparing support plans to effectively and appropriately use commercial support capabilities.
- Providing the infrastructure to use warranty service, when implemented.
- Creating an appropriate configuration management system.

SYSTEM INTEGRATOR/SYSTEM INTEGRATION AGENT (SIA)

The System Integrator/System Integration Agent (SIA) function is responsible for ensuring compatibility of all elements that make up a single system and for identifying/documenting the interface requirements external to the system throughout the system life. The SIA may be either a DoD activity or a contractor, but in either case, the SIA must maintain a close liaison with the other agents. A DoD ("in-house") activity is normally chosen for small-quantity acquisitions as NDI can often be purchased and integrated faster than an integration contract can be awarded. Furthermore, in-house SIA assets can be more responsive to rapidly changing user requirements when close liaison is needed between the TDA, SDA, and SIA. Contractor SIA assets are useful for very-high-quantity acquisitions. The large zone between these extremes can be satisfied by either in-house or contractor assets as long as the essential tasks are identified and accomplished. The SIA is normally responsible for demonstrating system performance, safety, operability, interoperability with interfaced/legacy systems, reliability, maintainability, and human factors performance. The SIA manages interfaces throughout the acquisition phase, monitoring system tolerances and error budgets for all elements of the system. Some or all of the SIA responsibilities may be transitioned to the LCMA for the operation and support phase. The following NDI issues are important to the SIA:

- Interface documentation, especially second-order parameters (essential interface characteristics not controlled explicitly by published interface specifications) and hardware/software interface requirements.
- Identifying, designing, and executing appropriate modifications.
- Acquiring non-off-the-shelf classes of NDI.
- Determining which system level of complexity best uses NDI and achieves the most affordable system implementation for the system life cycle. This includes meeting the safety, supportability, and human factors requirements while not imposing unreasonable or unaffordable modification requirements on the NDI candidates.
- Maintaining system conformity to changing operational requirements.
- Implementing requirements flowed down by the TDA or SDA.

The SIA may be the same activity as the SDA or LCMA or may remain an independent agent, depending on which issues are driving the acquisition and support decisions.

SYSTEM TEST AGENT (STA)

The System Test Agent (STA) supports the Manager and TDA in planning and directing all levels of the system test program. The STA serves as a direct liaison with the Operational Test and Evaluation Agency/Forces. The STA acquires access to test facilities (including operational forces) needed for system tests and demonstrations and oversees and analyzes results of tests done by other activities. The following NDI issues are important to the STA:

- Evaluating contractor conducted tests/test data.
- Determining test confidence levels.

- Designing screening tests for potential NDI.
- Evaluating demonstrations as a part of source selection.
- Test/conformance requirements within procurement requirements.

The STA function is sometimes shared between the TDA and SIA rather than being a separately identified agent. A separately identified DoD ("in-house") agent is recommended for NDI acquisitions because of the specialized expertise needed to address the above issues, even if that agent is a part of the same activity as the TDA.

LIFE-CYCLE MANAGEMENT AGENT (LCMA)

The Life-Cycle Management Agent (LCMA) is the DoD agent responsible for the overall coordination of the support management of the system from its acquisition through its phase-out and disposal. This level of system management includes system life-cycle planning and the coordination of activities assigned to the SDA, ISEA, SSA, SIA, STA, and TA. The following NDI issues are important to the LCMA:

- System life-cycle planning, including the planning impact on the system architecture and partitioning decision process.

- Specification control of the form, fit, and function of the system components, including all interfaces, across all installations.

- Advanced planning for support, including interim support requirements (which must take into account rapid acquisitions that may occur in substantially less time than normal support procedures can be implemented).

- Configuration management, especially configuration status accounting, across each installation.

- Life-cycle cost considerations throughout the system life and especially in source selection.

- Characterizing the market(s) supporting the system both technically and economically.

- Continuous market analysis/research promoting cost-effective support and product improvement decisions.

- Managing system requirements in post-acquisition phases, including product improvements. This is especially critical for requirements stemming from the system being a part of a larger set of systems forming an operational capability.

- Monitoring casualty reports, maintenance reports, supply reports, and other system metrics of the system and related/interfaced systems to ensure continued operational suitability.

- Establishing and coordinating organizational relationships that ensure that (rapidly changing) information is shared between the participating support agents. This includes coordinating ISEA and SSA support to users involving more than one ISEA and one SSA.

- Coordinating installations and improvement implementations with the planning organizations of the platform engineering and repair activities responsible for maintaining the platform configuration management. This includes participating in Class Improvement Plan Engineering/ Projected Class Baseline design efforts to ensure that the requirements generated are flowed into the system requirements appropriately and realistically. It also includes the coordination of alteration and repair packages among the multiple support agents.

- Ensuring that the multiple fielded configurations remain interoperable and maintaining plans to accomplish this. (This is especially critical for systems employing a substantial amount of integration software.)

The duties of the LCMA overlap substantially with the SDA during the acquisition phase, so the LCMA will normally also be the SDA when the SDA is not a contractor. The LCMA function includes the function of the Combat System In-Service Engineering Agent (CSISEA) sometimes identified by Systems Commands.

IN-SERVICE ENGINEERING AGENT/ACTIVITY (ISEA)

The In-Service Engineering Agent/Activity (ISEA), a DoD agent, performs design verification and validation, system assurance (especially safety and quality), documentation, production support, data analysis, maintenance engineering, installation design and support, fleet support of prototype systems, training and manning assistance, integrated logistics support planning, data management, configuration management, test/support equipment analysis and support, supply support planning, and repair facility planning and implementation support to the Manager throughout the post-acquisition/operations and support phase. The following NDI issues are important to the ISEA:

- Configuration management, especially Configuration Status Accounting, of multiple unique fielded configurations.

- Hardware–Software/Firmware interfaces and interface documentation/specifications.

- Uncontrolled changes/product improvements introduced by product suppliers.

- Implementing engineering changes into the system.

- Generating and maintaining accurate system metrics.

- Maintaining qualified sources of supply for spares/replacements.

- Managing contractor services, including warranty support.

- Enforcing warranty provisions in the field, including maintaining accurate warranty data.

SOFTWARE SUPPORT ACTIVITY (SSA)

The Software Support Activity (SSA) performs design verification and validation, system assurance (especially safety and quality), documentation, production support, data analysis, maintenance engineering, installation design and support, fleet support of prototype systems, training and manning assistance, integrated logistics support planning, data management, configuration management, and software/firmware test/support equipment analysis and support to the Manager throughout the post-acquisition/operations and support phase for system software. The SSA usually provides the planning and implementation of the Computer Resources Life-Cycle Management Plan as tasked by the Manager. The SSA controls and coordinates the distribution of software releases to the user community. In addition, the SSA often also provides independent verification and validation services, independent software quality assurance services, and/or independent testing services during developments, including modified NDI and integrated NDI. This promotes the smooth transition from the acquisition phase into the support phase. The following NDI issues are important to the SSA:

- Configuration management, especially Configuration Status Accounting, of multiple unique fielded configurations.

- Hardware–Software/Firmware interfaces and interface documentation/specifications.

- Uncontrolled changes/product improvements introduced by product suppliers.

- Implementing engineering changes into the system.

- Generating and maintaining accurate system metrics.

- Documenting system requirements for the hardware–software or hardware–firmware interface.

- Tailored support of NDS, including the requalification of NDS and modified NDS changes.

- Documenting modifications and new designs in modified NDI and integrated NDI.

The SSA is almost always a DoD agent; however, SSA functions have been successfully contracted to an industry agent under the limited circumstances of wholly proprietary software that has been specially modified for system requirements. When the SSA function is contracted out, the LCMA or ISEA should normally control the contract.

TRAINING AGENT/ACTIVITY (TA)

The Training Agent/Activity (TA) is the agent for the cognizant DoD personnel and training command (Chief of Naval Education & Training (CNET) in the Navy) for the training life-cycle support of the system. The TA is responsible for maintaining current training for the system. This includes the materials and curriculum for any on-the-job or embedded training as well as training at schools. The TA also oversees the conduct of the training to ensure training quality and may also oversee personnel qualification standards. The following NDI issues are important to the TA:

- Maintaining quality, cost-effective training.

- Maintaining accurate training documentation.

- Consistency of system documentation with the delivered product (this being a serious potential problem as the product may change significantly over its life).

- Multiple fielded configurations of the system with different operation and maintenance characteristics (and potentially unique training requirements).

- New skill requirements being introduced by product improvements (especially those product improvements introduced in COTS equipments that are not ordered in the acquisition of the system or its replacement parts).

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13. ABSTRACT *(Maximum 200 words)*

This document summarizes the best practices and lessons learned in several decades of acquiring Non-Developmental Item (NDI) systems. These processes have been codified into a tailorable process and several subprocesses. This process has been reconciled with the Center systems engineering processes and practices to ensure its practical applications. The process also introduces the concept of a system life-cycle management agent responsible for overseeing the process application throughout the system life cycle. The heavy application of NDI to system acquisitions raises a variety of very significant issues that must be resolved across traditional organizational boundaries and that require the coordination of a variety of engineering expertise; the system life-cycle management concept provides for this technical coordination and ensures that appropriate expertise is applied to the resolution of these issues.

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